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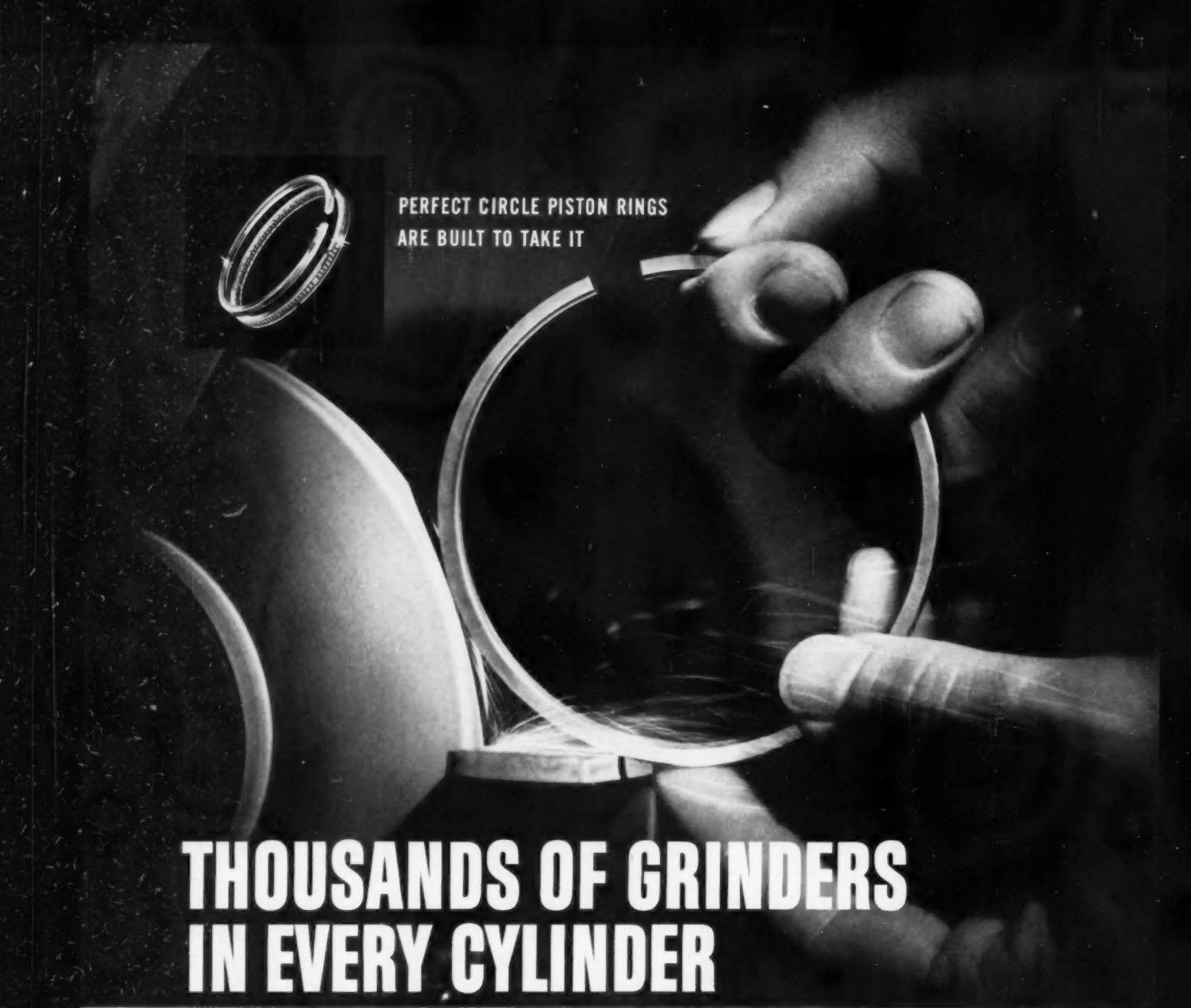

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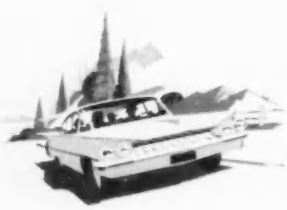

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To protect our ICBM's from surprise attack 27

The program to protect our retaliatory ICBM's from a surprise attack before they are launched includes the use of hard launching sites and design of ICBM's so that they are adaptable to mobile launching from air, land, or sea craft. — **W. R. Stumpe and M. V. Kadlick**

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A new research tool — a quartz piston engine — developed at GM Research permits an unobstructed view of the combustion processes occurring in overhead-valve combustion chambers of compression ratios as high as 10.7/1. (Paper No. 150B) — **Fred W. Bowditch**

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The modern airbrake is a vast improvement over that of 30 years ago. But even greater advances lie ahead, both in the foundation brake and in the air supply. (Paper No. 184B) — **R. B. Palmer**

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Elastomer coatings have solved the acoustic fatigue problem on the Navy A3D airplane. Stresses were reduced from ½ to ⅓ of their original levels when elastomers were applied at critical locations. (Paper No. 164A) — E. W. Thrall, Jr.

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Comprehensive 1000-page manual is one-stop reference for designing fluid thermodynamic airborne space vehicle systems. Basic data, however, apply to thermodynamic problems in aero-space and ground vehicle industries.

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SAE JOURNAL, July, 1960, Vol. 68, No. 7. Published monthly except two issues in January by the Society of Automotive Engineers, Inc. Publication office at 10 McGovern Ave., Lancaster, Pa. Editorial and advertising department at the headquarters of the Society, 485 Lexington Ave., New York 17, N. Y. $1 per number; $12 per year; foreign $14 per year; to members 50¢ per number, $5 per year. Entered as second class matter, Sept. 15, 1948, at the Post Office at Lancaster, Pa., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in the Act of Feb. 28, 1925, embodied in paragraph (d-2), Sec. 34.40, P. L. and R., of 1918. Additional entry at New York, N. Y. Second class postage paid at Lancaster, Pa. and additional office N. Y. C.

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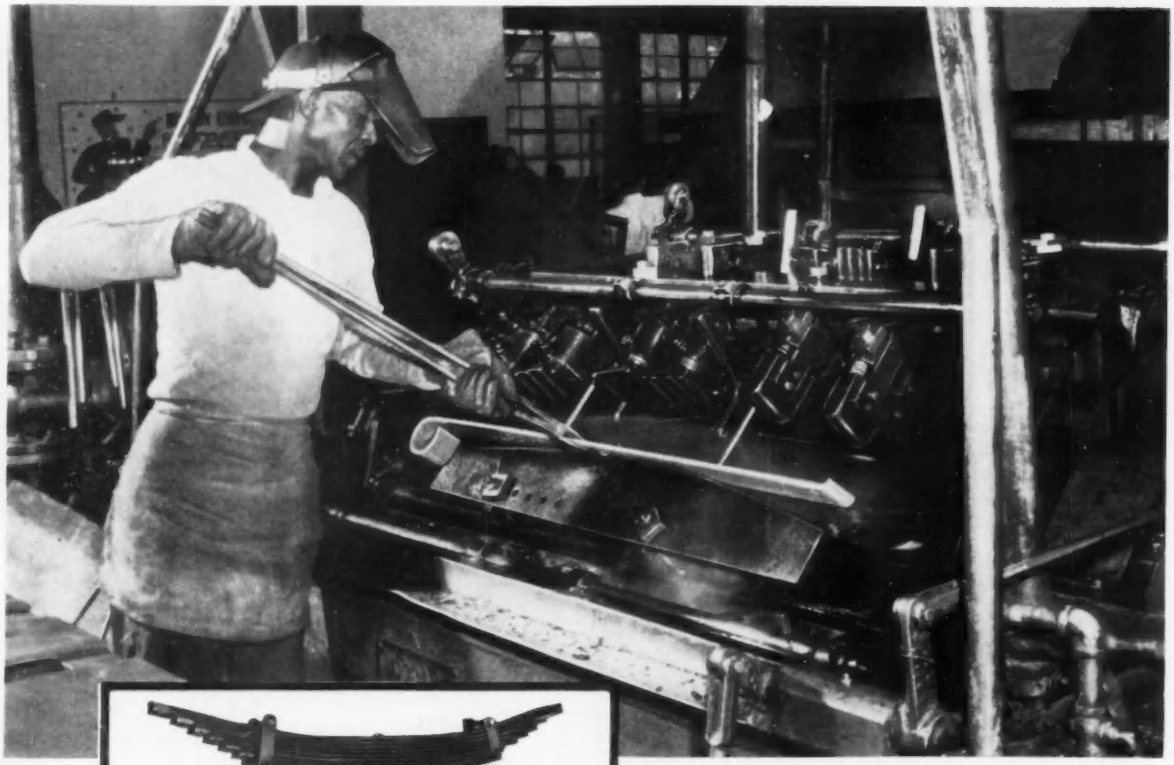

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AIRCRAFT

Selection of Accessory Power Systems for Long-Duration Manned Space Vehicles, E. T. RAYMOND. Paper No. 154A. Boeing Airplane Co. study to determine feasible power units for producing 5 kw of electric power continuously and 10–20 hp of hydraulic power intermittently, primarily during reentry; examination of solar power systems, such as direct photovoltaic power conversion; static conversion of solar heat to electricity, and solar heat to electricity by dynamic means; use of radioactive isotope as heat source and controlled fission within reactor.

SNAP 2 — Reactor Powered Turboelectric Generator for Space Vehicles, G. M. ANDERSON. Paper No. 154B. Report of SNAP 2 project to develop space power system for use in 1962–1963 in surveillance of communication satellites, space station power systems, etc; characteristics of reactor using (Zr-U) $H_{1.7}$ as fuel; Rankine cycle and mercury as working fluid; system schematic, components and flow of working fluids; conversion equipment test program, steps for future development.

Heat Transfer Problems of Space Vehicle Power Systems, R. A. TRUSELA, R. G. CLODFELTER. Paper No. 154C. Problems in energy conversion systems considered by U. S. Air Force following areas: working fluids, emissivity, boiling heat transfer, and condensing; zero gravity experiments, by Wright Air Development Div.; behavior of gas released in fluids and effect of surface tension; mercury condensing and pyrex boiler condenser tests; fluid orientation and pumping tests; thermal energy storage; meteorite protection.

Basic Studies on Base-Metal Thermocouples, J. F. POTTS, Jr., D. L. McELROY. Paper No. 158A. Details of studies, conducted up to 2000 F at Oak Ridge National Laboratory and University of Tennessee to improve thermoelectric measurements through better understanding of basic behavior of thermocouples; answers were sought to question of reliability of Chromel-P/Alumel for measuring temperature up to 1000 C and whether better combination exists; materials tested and results of comparison calibrations of samples; two examples of short-range diagnostic studies.

Materials for High (2500–4000 F) Gas Engine Temperature Measurements, A. R. ANDERSON, D. J. MacKENZIE. Paper No. 158B. Present state of materials available for use as thermocouples; thermoelement materials to withstand temperatures approaching or exceeding 4000 F in either oxidizing, reducing, inert, or vacuum atmospheres; wire combinations; insulation materials, such as zirconia, alumina, magnesia, beryllia, and thoria; insulation resistance factor; sheath materials and comparative merits examples of probes used to measure afterburners.

Design Procedure for Thermocouple Probes, L. B. HAIG. Paper No. 158C. Method of reducing environmentally induced errors of thermocouples in gas stream temperature measurement; basic heat transfer concepts used in design of probe envelope provide environment for junction conducive to accurate gas temperature measurement; procedure illustrated by design of probe in range of 100 F with error limit of 0.2 F at Mach numbers ranging from 0.2 to 1.0; test results show maximum error of 0.18 F. substantiating procedures; example relating to gas turbine.

Experimental Determination of Thermocouple Time Constants with Use of Variable Turbulence, Variable Density Wind Tunnel, and Analytic Evaluation of Conduction, Radiation, and Other Secondary Effects, A. F. WORMSER. Paper No. 158D. Parameters not normally considered in reporting, specifying, and predicting thermocouple time constants found to be significant are: airstream turbulence, step change size, variable wire specific heat, axial conduction, and temperature ratio; apparatus used in study made by General Electric Co. and resluts obtained; pertinence to jet engine measurements.

Intercomparison of Thermocouple Response Data, F. R. CALDWELL, L. O.

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OLSEN, P. D. FREEZE. Paper No. 158F. Cooperative project initiated by SAE Committee AE-2, Physical Measurement Sensing, to determine effects of temperature on time constant or characteristic time of thermocouples, used to measure jet engine temperatures; account of work done at three laboratories: General Motors Research Laboratories, Orenda Engines Ltd., Toronto, Can., and National Bureau of Standards; discussion of results.

Dynamic Testing of Gas Sampling Thermocouples, J. D. MEADOR. Paper No. 158G. Performance characteristics of gas sampling thermocouples used in monitoring of turbine inlet gas temperatures of Allison Model 501 engine; environmental factors affecting performance of thermocouple analyzed and criteria established for testing of such components; new high-temperature flowing gas thermocouple test rig and performance data; schematics illustrating characteristics of thermocouple and features of test equipment.

Time Response Characteristics of Temperature Sensors, M. D. SCADRON. Paper No. 158H. In order to better evaluate ability of thermocouple type sensor to accurately respond to changes in environment temperature, techniques are presented to determine how fast sensor will respond to changes in medium temperature when it can transfer heat conduction, radiation and forced convection; how time constant is affected by choice of wire is shown.

Engineering Standards for Comparison of Direct Electrical Conversion Devices, F. W. ANDERS. Paper No. 159A. Method of assessing state of art of laboratory techniques in energy conversion areas which emphasizes comparative merits of various technologies without including large mass of detailed engineering data; energy conversion matrix representing ideas which will be investigated during next decade; fuel cells, batteries, turbines, and other devices are included; results of questionnaire sent to 200 industrial activities showing processes being investigated.

Thermoelectric Air Conditioning Module for Sealed Cabins, H. L. HALL, P. L. CATRON. Paper No. 159B. Feasibility study at Douglas Aircraft of system for use in space vehicles, etc, considers thermoelectric cooling by use of Peltier effect to serve as heat pump portion of refrigeration system; functions of absorbing carbon dioxide and replenishing oxygen are performed through KO_2 bed where CO_2 is absorbed and O_2 liberated; three modules form cooler incorporated into feasibility model; equations to calculate cooler performance and guide lines for design of module.

Thermionic Power Converter and Its Applications, J. G. LEISENRING. Paper No. 159C. Fundamental operating characteristics of thermionic converter used in power conversion systems as electrical power generator or high-temperature sensor in space, airborne, ground, or sub-surface systems; heat source selected may be chemical, nuclear, or solar energy; work reported was done under direction of Ballistic Missile Div. U. S. Air Force and General Electric Co., Missile and Space Vehicle Dept.

Solar Concentration Cells, B. H. CLAMPITT, D. E. GERMAN. Paper No. 159F. Device proposed by Boeing Airplane Co. employs 2-stage process with first stage being conversion of solar to chemical energy and second stage of chemical to electrical energy; solar energy is stored by photochemical isomerization of trans to cis organic acids; because of difference in hydrogen ion concentration electrochemical concentration cells can be constructed from cis and trans acid solutions, and portion of chemical energy recovered as electrical energy; pertinence to satellites.

Fuel Cells — Technical and Economic Study, A. M. MOOS. Paper No. 159D. Evaluation methods range from classification based on electrolyte as aqueous and non-aqueous, to classification as direct or indirect (redox cells;) technical feasibility was shown in following systems: low temperature (50–150 F) 1-p (1-50 psi) hydrogen oxygen or air fuel cells; medium temperature (400–600 F) and high pressure (400–1000 psi) hydrogen-oxygen fuel cells; low temperature fuel cells using hydrocarbon fuels and oxygen; high temperature (400–1000 F) fuel cells using hydrocarbons and air; military and commercial applications.

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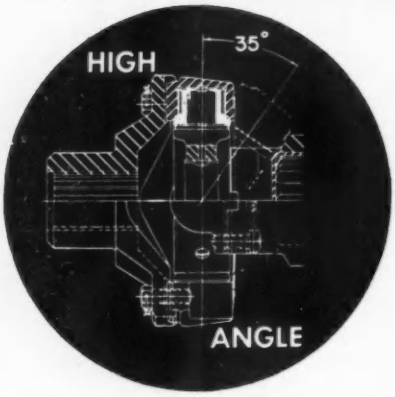

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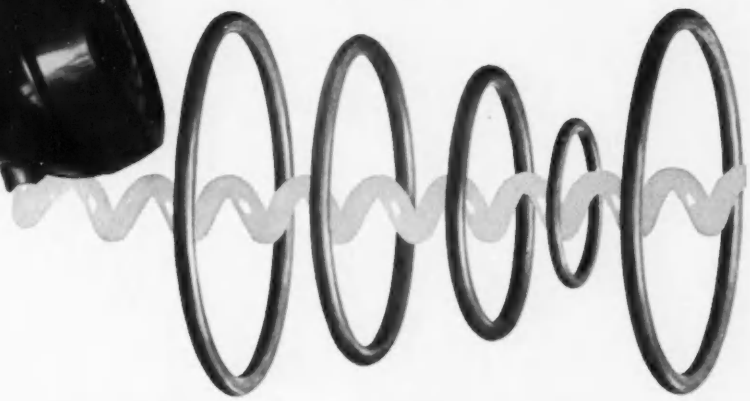

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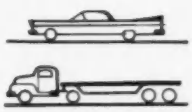

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You may wish to refer to the Rollway Catalog and Engineering Data Book when writing specifications for a high precision bearing. It contains the first listing, by any manufacturer, of the thrust capacities of cylindrical radial roller bearings. Send for it today.

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Jet brake cup — LS-53
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Diesel equipment seal — Viton
Drop-off tank seal — LS-53
Chemical pump liner — Viton
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For advanced fuel...hydraulic...lube systems,

New materials prove ideal in handling temperature extremes −350° F. to +750° F.

Working with two remarkably versatile elastomers, C/R Sirvene engineers are producing flexible molded parts for many vital fuel, lubricating, hydraulic and pneumatic systems. One, Viton-A*, can be compounded to produce parts that function dependably at 600° F., and for short periods up to 750° F. The other important feature of Viton compounds is their excellent resistance to corrosive chemicals, chlorinated solvents as well as both synthetic and petroleum base fuels and lubes. At the other extreme, C/R compounded Silastic LS-53** parts are providing low temperature operation down to -80° F. They also exhibit excellent resistance to synthetic and petroleum base fluids up to 350° F., and function well in propane up to 500° F. For temperatures as low as -350° F., C/R recommends Teflon* compounds.

C/R Sirvene engineers have an intimate knowledge of these elastomers. They also have perfected special techniques in processing which still further improve the physical properties of the molded parts. If your problem involves high or low temperatures, close tolerances, and compatibility in advanced design fuel, lubricant or hydraulic systems, get in touch with us at once. We have the skill and the facilities to help you.

* DuPont registered trademark
**Dow-Corning registered trademark

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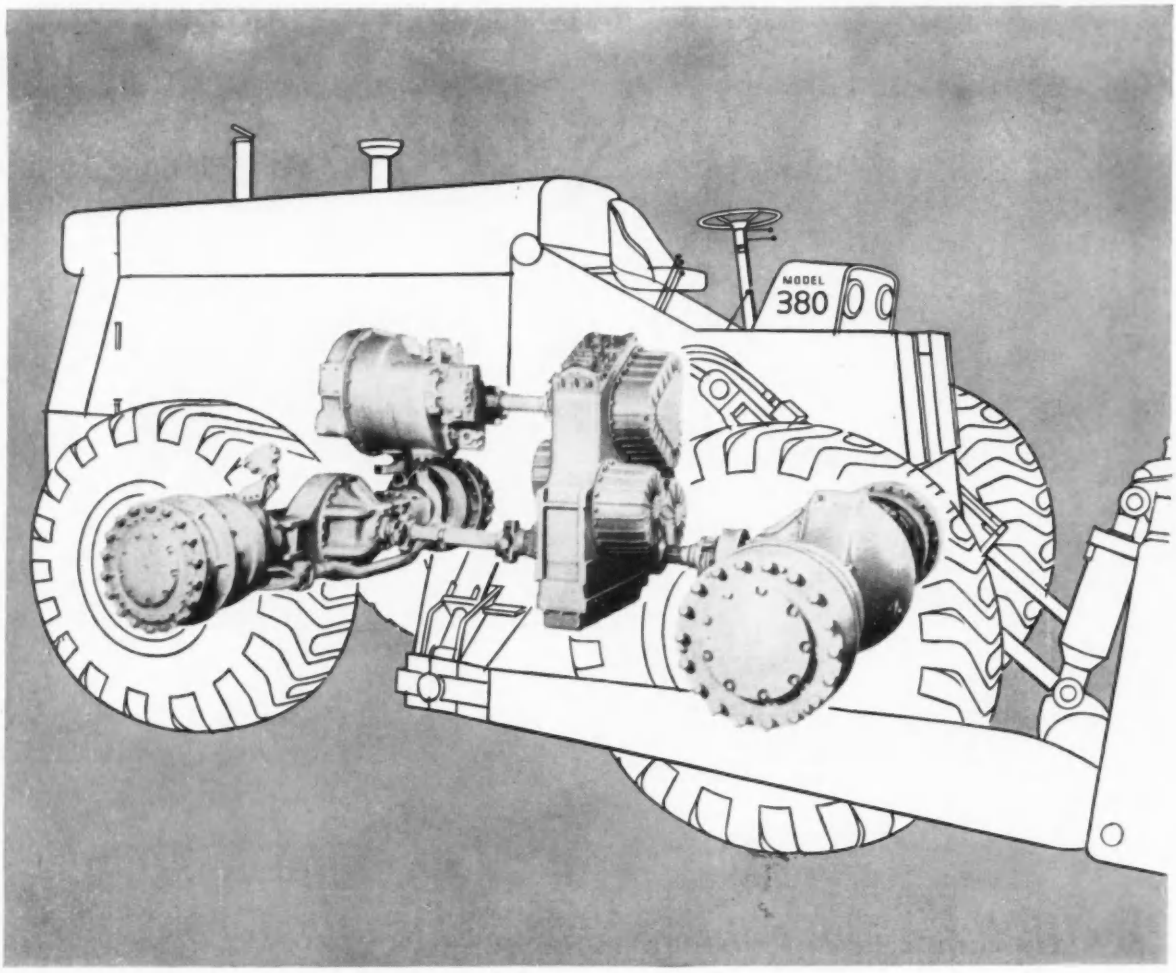
C/R PRODUCTS: C/R Shaft & End Face Seals • Sirvis-Conpor mechanical leather cups, packings, boots • C/R Non-metallic gears

C/R



Nickel steels in this power train give miles and months of extra service

For an extra measure of resistance to the shocks and stresses of earth-moving, here's where Clark Equipment Company relies on nickel alloy steels in the tough, dependable power train used in Michigan tractor-dozers.

Every shaft, gear and pinion in the mechanical gear train is made of AISI 4817 steel. This 3½% Nickel steel combines tough core strength with high surface hardness for outstanding resistance to shock and wear. These heavy-duty carburizing properties are liberally designed into final drives, too: the planetary sun gear and spiral bevel gear and pinion are all made of AISI 4817.

For clutch drums and internal planetary ring gears, the choice is 8620 steel. With excellent response to heat treatment, this Ni-Cr-Mo carburizing steel provides a hard, wear-resistant case backed up by a tough core to resist heavy compressive loads.

For strong, light-weight scraper yokes, Clark uses "T-1"* Steel, a quenched and tempered constructional alloy steel containing Nickel and other elements. Three times stronger than standard steels, "T-1" may be used in lighter section to fabricate strong structural members.

The best design for off-road service often depends on properties like these. To satisfy your strictest requirements, you can find in a particular nickel alloy steel the specialized properties you want. All are readily available. And for help in finding practical solutions to materials-selection problems, simply write to Inco. *Reg. trademark, United States Steel Corp.

THE INTERNATIONAL NICKEL COMPANY, INC.

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INCO NICKEL

NICKEL MAKES STEEL PERFORM BETTER LONGER

Photo courtesy International Harvester

How R/M helped develop unusual wet friction application for International Harvester

Can you imagine the friction problem created in braking and turning a crawler tractor like this?

That's the problem International Harvester engineers faced in 1948 when they designed the TD-24 crawler tractor. Plans called for a wet friction application in the steering system. Wet friction was pretty new in construction equipment 12 years ago. So it was natural that I.H. called on Raybestos-Manhattan's friction "know-how."

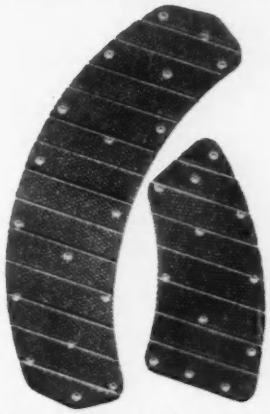
Woven asbestos

R/M friction specialists tackled the problem and came up with an unusual shaped woven asbestos brake lining material. It has shown phenomenal resistance to wear under rugged service conditions. In fact, it was so successful that International Harvester continues to use it in the Planet Power steering of such new tractors as the 22 ton, 230 hp TD-25 shown above.

Service, quality, competitive prices

Only R/M manufactures all types of friction materials—your assurance of sound, unbiased recommendations on the material best for your needs. So next time you have a friction problem, why not see what R/M can do. Large field engineering staff and extensive laboratory facilities are all set to work for you. As one customer put it, "We get this extra service, yet prices are competitive; quality is uniformly high." Call us—an R/M sales engineer can be at your desk within 24 hours.

Want helpful engineering data on friction materials? Send now for R/M Bulletin 501—no obligation.



R/M woven asbestos brake linings for Planet Power steering—an independent two speed power-shift planetary transmission on each side of bevel gear and pinion. Each controlled by three discs for low and high ranges, pivot brake. Hydraulic actuated brake shoe, lined with R/M material, stops selected discs; allows power to flow to the crawler track in that speed range. Splash and pressure lubricated; oil helps cool.

R/M

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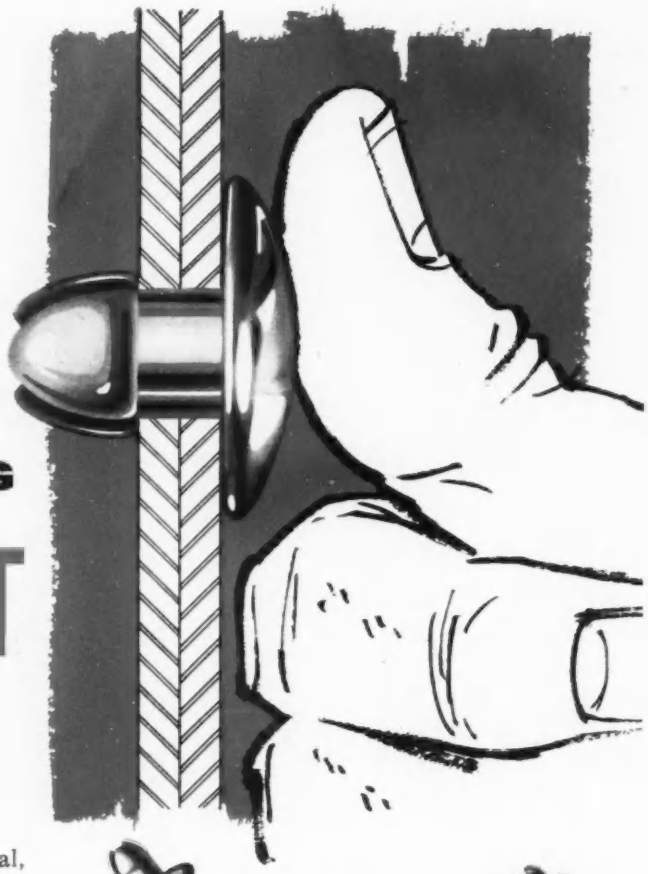
or parts . . .



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TRIMOUNT STUDS

Designed for rapid assembly of sheet-metal, plastic or composite structures, Dot Trimount studs are available in both permanent and removable types. They can be pushed into drilled, stamped or molded holes by finger-pressure alone yet they lock positively in place and resist constant vibration.

Studs can be designed in steel or brass with various flange configurations for clinch, clip or clamp attachment to flexible or rigid panels as well as for push-through assembly. Available in all standard finishes . . . with or without decorative caps.

Push Rivet Stud
Shoulder Type (Capped)

Push Rivet Stud
Tapered Type (Capped)

Push Rivet Stud
Shoulder Type (Not Capped)

Push Rivet Stud
Tapered Type (Not Capped)

Clinch Type Stud

Clip-on Stud

Trim Stud
Barrel Type

Trim Stud
Scissors Type

Panel Type Stud

Loop Type Stud

Panel Stud
Staple Type

Panel Stud
Hook-on Type

DESIGN ENGINEERING SERVICE

Designers, metallurgists and plastics specialists on Dot's engineering staff are equipped to work out optimum combinations of metal and plastics to suit your particular requirements.

▶ *For further details, write for Engineering Data Catalog, Section H*

MAKERS OF DOT FASTENERS

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URETHANE RUBBER POLYMERS

New Urethane Elastomers That Combine Hardness, Resilience and Exceptional Load-Bearing Capacity

ADIPRENE polymers are members of Du Pont's new urethane rubber family. These urethane polymers can be compounded in a wide range of hardnesses and retain their elastomeric properties throughout this range. They combine the resilience of rubber with the hardness and load-carrying capacity normally associated with many metals and hard plastics. To engineers, they provide a new class of materials and a new approach to automotive design problems.

Products made from ADIPRENE urethane rubbers are well suited for service in lubricating oils, greases and automotive fuels. They withstand attack by ozone and oxygen and are resistant to salt solutions, dilute mineral acids and bases. ADIPRENE compounds also have outstanding resistance to abrasion and impact and excellent low temperature properties. (Low temperature brittle point less than –80° F.)

Most of the raw ADIPRENE polymers are liquid at room temperature, which makes them ideal materials for casting complicated molded parts. Vulcanized, high durometer compounds are as machinable as some metals. They can be drilled, turned and shaved on standard metal working equipment.

These properties of ADIPRENE polymers suggest a wide range of automotive applications. Current and potential uses include: seals, grommets, bushings, ball joint liners, engine and body mounts, striker plates, encapsulated electrical assemblies, abrasion-resistant coatings for underbody parts and solid industrial tires for manufacturing plants. ADIPRENE elastomers should be treated as new materials, and parts designed to take full advantage of their special properties. Mere substitution of an ADIPRENE in an existing design may not produce optimum results.

We will be glad to send you complete information on the engineering properties and performance of ADIPRENE urethane rubbers. We'll also begin your free subscription to the quarterly, ELASTOMER NEWS FOR AUTOMOTIVE ENGINEERS. Just write: E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Dept. SAE-7, Wilmington 98, Delaware.

PROPERTIES OF CURED ADIPRENE POLYMERS

*Hardness, Shore A	75	88	95	97	99+
Hardness, Shore D	—	43	50	60	78
Modulus, 300%, psi	1100	2100	3200	7000	—
**Tensile Strength at Break, psi	4500	7000	8825	8500	8500
Elongation at Break, %	400	450	480	340	250
Izod Impact Notched ft.-lbs./in.	Flexed	Flexed	Flexed	>20	1.2
Split Tear, ASTM-D 470 lbs./linear inch	25	50	155	160	200
***Compression/Deflection, psi @ 5% defl.	250	575	750	1800	6000
Rebound Resilience, %	45	45	40	42	45
Oil Resistance	Good	Excellent	Excellent	Excellent	Excellent
Low Temperature Brittle Point, °F.	<-80	<-80	<-80	<-80	<-80

*Softer compounds ranging from 10 Shore A are also available.
**Samples pulled @ 1 in./minute (elastomer stocks normally pulled @ 20 in./min.)
***Shape Factor—1.0

SYNTHETIC RUBBER
NEOPRENE HYPALON® VITON® ADIPRENE®

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...through Chemistry

The "custom" approach to oil seal manufacture, pioneered by IPC, has resulted in some real off beat products.

None-the-less . . . they *work!* They suit the application *and,* in more cases than not, they have contributed substantially to cost savings.

When you're faced with a rugged problem involving oil seals, what synthetic compound comes to mind? How about case design? . . . friction? . . . torque? . . . shaft speeds?

Oil seals are an engineered product in themselves . . . just as good as their individual design. That's why we think each oil seal application deserves special "custom" thinking. That's why IPC oil seals are noted for performance. Let us show you what IPC can do to relieve your particular problem.

OIL SEALS / PACKINGS / PRECISION MOLDING *Custom designed for your application.*

IPC **INTERNATIONAL PACKINGS** CORPORATION

Bristol, New Hampshire

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P-1

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WAUKESHA TRANSPORT ENGINES

up to 400 HP

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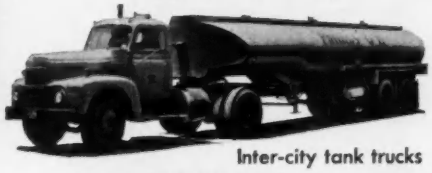
- *Economy*

Heavy materials delivery

Heavy-duty hauling

Steep-grade transport



Inter-city tank trucks

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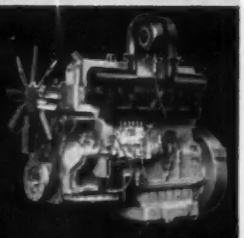
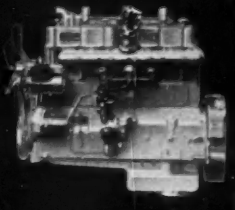
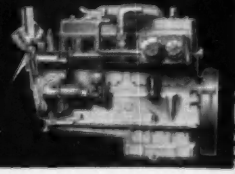
WAUKESHA WAKDBS TURBOCHARGED DIESEL...
6¼ x6½" bore and stroke, 1197 cu. in. displ., up to 400 hp. at 1800 rpm.



WAUKESHA 145-GZB HIGH OUTPUT GASOLINE ENGINE
5½ x6" bore and stroke 817 cu. in. displ., up to 268 hp. at 2400 rpm.



WAUKESHA WAKB BUTANE-PROPANE ENGINE
6¼ x6½" bore and stroke, 1197 cu. in. displ., up to 300 hp. at 1800 rpm.



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EXCEPTIONAL PLANT FACILITIES
25 ACRES OF MANUFACTURING SPACE

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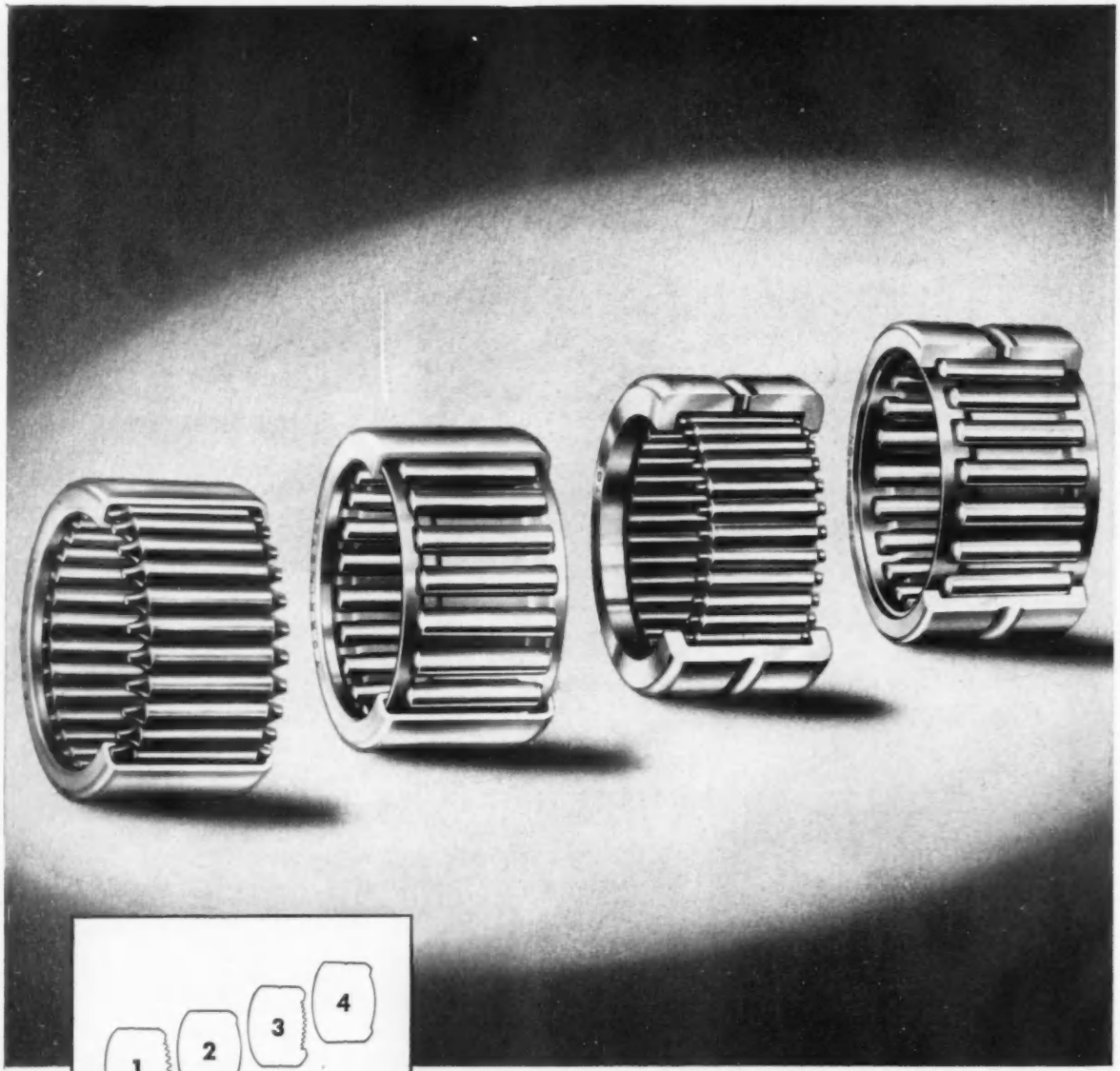

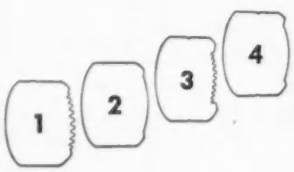

Torrington Drawn Cup Needle Bearing . . . for maximum radial capacity in minimum cross section . . . positioned by press fit—snap rings or shoulders unnecessary . . . runs directly on hardened shaft . . . most compact, light weight, economical.

Torrington Drawn Cup Roller Bearing . . . for higher speeds or long pregreased life . . . thin section race for simple press fit . . . runs directly on hardened shafts . . . unit construction for easy assembly . . . shaft-riding retainer.

Torrington Heavy Duty Needle Bearing . . . for use with thin section or split housing where extreme impact loads require heavy outer race . . . maximum shock resistance . . . full roller complement . . . unit construction.

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All of these types of bearings are available with inner races.

Only Torrington Makes All Four!

Torrington developed the Needle Bearing and its specialized variations. This breadth of experience assures impartial engineering recommendations based on specific application requirements. You can rely on Torrington to recommend the most compact and economical design compatible with operating conditions and performance requirements. Call on your Torrington representative for help in applying the right bearing in the right place. **The Torrington Company, Torrington, Conn.—and South Bend 21, Indiana.**

TORRINGTON BEARINGS

Every Basic Type of Anti-friction Bearing

NEEDLE • SPHERICAL ROLLER • TAPERED ROLLER • CYLINDRICAL ROLLER • NEEDLE ROLLERS • BALL • THRUST

SAE JOURNAL

For Sake of Argument

Decisions and Fears . . .

CHANCES ARE we all get fears mixed up in our decision-making more than we like to admit . . . probably more than we even know.

How often is our caution mere hesitancy; our long, careful analyses really fear of the consequences of a decision? How often do we rationalize our vacillation as prudence; our pausing as forethought; our doubting as calculation?

How often do we hide behind the old Haitian maxim or its equivalent: "Never insult an alligator till after you have crossed the river" . . . when we're just plain scared of drowning?

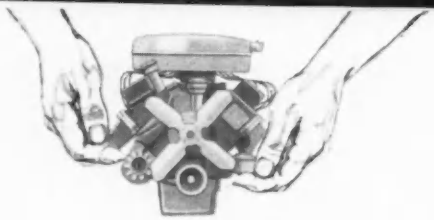
Fear is as often the spark to sudden, unwise action as to continued indecision. It can act as might a sudden gunshot to a man crossing Niagara Falls on a tightrope. We've all been involved in decisions which resulted because somebody — maybe ourselves — was frightened.

Whatever its part in decision or action, the effect of fear is malignant, never benign. It never accomplishes anything good.

Fear has reality only to the mind which possesses it . . . or to the mind which it possesses. It is hard on everybody; hardest on us when we hold it.

Fear is hard on everybody in its vicinity because it breeds weakness . . . and "Weakness," according to Dwight Eisenhower, "can't cooperate with anything."

Norman G. Shidle



. . . design Creativity

Should piston rings be coated or sprayed with aluminum oxide to counteract abrasive action in aluminum engines? Are locked rings really necessary for V and flat engines? Are moly-coated rings the real answer in aluminum bores? Hundreds of such engine problems are being worked out today on dynamometers in the Ramco plant . . . on the highways . . . on the proving grounds of car and truck factories. Products of Ramco's design creativity are constantly on test and proving our slogan, "Give the Gentleman what he wants" . . . give the immense automotive industry the kind of cooperation in engineering effort that is sought . . . the full cooperation of TRW's resources and experience . . . the completely-manned engineering team and production know-how of one of the world's most modern piston ring plants. The story of our piston ring facilities is contained in a new book. May we send you a complimentary copy?

Piston Rings by THOMPSON PRODUCTS RAMCO DIVISION

Thompson Ramo Wooldridge Inc. • P. O. Box 513 Dept. Q, St. Louis 66, Mo.

AUTOMOTIVE GROUP

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from SAE meetings, members, and committees

FIXED COSTS TO OPERATING COSTS average 70%/30% for passenger cars and 20%/80% for highway tractors.

The cost of fuel amounts to about 46% of the cost of owning and operating a highway tractor compared to 19% for a passenger car.

An improvement of 10% in highway tractor fuel economy results in a decrease of 4.2% in total ownership costs. In contrast, 10% increase in passenger car fuel economy amounts to a decrease of less than 2% in annual costs.

A 10% decrease in maintenance cost results in a 3% decrease in annual truck costs compared to less than a 1% decrease in annual car costs.

A 10% decrease in the initial price of a car will result in a 7.3% decrease in car annual cost of ownership; in the case of the truck this 10% decrease would amount to only 1.2% of the total annual cost.

THE FEDERAL AVIATION AGENCY, by the end of January, had certified 12 turbine transports and received applications for certification of 25 other turbine transports and three turbine-powered helicopters. The transports already certified are:

Fairchild F-27 (Dart)
Lockheed Electra (501–D13)
Boeing 707–100 (JT3C)
Grumman 159 (Dart)
Boeing 707–300 (JT4A)
Douglas DC-8 (JT3C)
Douglas DC–8 (JT4A)
Vickers Viscount 745 (Dart)
Fokker Friendship (Dart)
Bristol Britannia 305 (Proteus)
Vickers Viscount 810 (Dart)
Caravelle SE 210 (Avon)

In addition, the Napier Eland Convair conversion of the CV340 to turbine power has been approved, under the provisions of Part 4b and Special Regulation SR-423.

THE OPTIMUM CAR from the engineering point of view would be a 2200-lb car. From the point of view of the consumer, however, it appears that the 2400 lb car is the optimum economy car.

DUTY ON U. S. CARS entering Germany is 13%, France 29%, England 30%, and Italy 40½%. The U. S. duty on imported cars is 8½% ad valorem.

TO DEVELOP AN AUTOMOBILE UPHOLSTERY FABRIC takes the fabric manufacturer from three to six months, on the average. Sometimes it takes even longer to meet the rigid tests which each automobile manufacturer has set up.

One basic construction, however, usually meets the requirements and has come to underlie most car upholstery fabrics made today: a nylon filament warp and spun filling yarns of rayon or cotton, and mixtures of fibers of this type.

BALLISTIC MISSILES from one continent to another take a maximum of 30 min to target, according to Admiral W. F. Raborn, Director, Special Projects, U. S. Navy Bureau of Weapons.

A TURBOJET THRUST AUGMENTOR has been developed by Continental for use with pyrophoric fuels. This augmentor is only one-half as long as a comparable augmentor designed to use JP-4. Experiments show that the mixture of ¼ TEA (triethyl aluminum) and ¾ TMA (trimethyl aluminum) gives better combustion efficiency at altitude than either fuel used by itself.

WHETHER OR NOT A SPACE VEHICLE IS TO BE MANNED is of particular importance when dealing with a nuclear energy source. The need to protect men from nuclear radiation may increase shielding weight by as much as 400% over that required to protect sensitive equipment.

AS AIRCRAFT TURBINE ENGINES ARE FURTHER DEVELOPED, they impose additional quality requirements on the fuel. One new requirement which was added recently is a thermal stability test, usually conducted at 300 F and 400 F. This test measures any tendencies the liquid fuel may have to form deposits in certain parts of the engine's fuel system which are exposed to high temperatures.

Another fuel test requirement that may be added shortly to some jet fuel specifications is a Luminometer rating. The Luminometer is a laboratory apparatus which measures the luminosity or radiation characteristics of the flame. Extensive testing in some of the latest high performance turbine engines has shown that variations in flame luminosity affect the working temperature of

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. . . continued

the engine parts in the combustion zone that "see" the flame. The more radiant flames can thus have a deleterious effect and shorten the life of such parts.

AUTOMATED HIGHWAY DESIGN is predicted in the foreseeable future by Basil Mikhalkin of Bendix Computer Division. Data will be taken photogrammetrically and punched up automatically in terms of digital terrain models. The location of property lines and values of property will be fed as input into a computer with a per unit set of construction costs. The computer will then try various alignments, choose the most economical alignment as far as right-of-way costs and construction costs, and run through and produce a completed design.

HIGH-ENERGY FORMING methods are shaping metals at hundreds of feet per second. This compares with a metal form rate of up to 5 fps for conventional forming methods. In addition, where forming pressures up to 10,000 psi can be obtained by conventional means, high-energy forming permits forming pressures in the magnitude of hundreds of thousands of pounds.

NASA IS EXPERIMENTING WITH FLEXIBLE, VERY LIGHT-WEIGHT GLIDERS for recovering payloads reentering the earth's atmosphere. Some of the low-speed models are fabricated of aluminized polyester film in very fine gages. Others are made of impregnated fabrics with inflated or stiffened leading edges.

TIME STUDY is best applied to operations where the process time is greater than the manual time . . . when the operator's method affects time more than his effort . . . and to high volume repetitive work. This conclusion is based on the experience of production-knowledgeable engineers who exchanged ideas about time study at a recent SAE Production Forum. "The stop watch," one said, "can be read to 0.01 min, but cannot be accurately read unless the preceding or succeeding element is a much longer element."

Studies are seldom closer than ±5% because of performance rating variations.

FIVE KINDS OF ENGINEER plus an economist must combine talents to properly design convection into a heat-treat furnace, according to J. Huebler of Surface Combustion.

A metallurgist is needed to set time and temperature uniformity specifications . . . an aerodynamist to analyze and predict the flow of wind . . . a heat transfer specialist to calculate how rapidly and how uniformly the load can be heated . . . a structural designer to design the fan, the duct systems, and the furnace enclosure . . . and a materials handling engineer to find the best way to bring the work to the furnace, through the furnace, and away from the furnace.

"And, of course," Huebler comments, "governing all these analyses is the primary objective of all engineering: economics."

NOWADAYS PILOT TRAINING DEVICES AREN'T CHEAP — The flight simulator for the B-70 costs as much as the bomber itself.

WEDDING BELLS YIELD TO NAVY BELLS — Nick Magyar, newly appointed chairman of Committee A-12, Aircraft Landing Gear, Shock and Control Mechanisms, found that his daughter's wedding plans conflicted with the next meeting of his committee. Because this meeting was scheduled to be held aboard an aircraft carrier, Miss Magyar graciously bowed to the Navy and rescheduled her wedding plans.

A POUND OF WEIGHT SAVED in future trisonic jet transports will be worth four times as much as the same pound saved in today's piston-engine transport. This weight advantage will help designers justify high performance but high priced materials. It's a good thing, too, as conventional materials like aluminum won't stand up to the 600 F temperatures expected.

MORE THAN 500 DEGREES OF FREEDOM might be required of a mathematical model to adequately describe an automobile structure with engine and suspension says Earle Stepp of Chrysler. Such a system is far too complex to attempt to predict or evaluate with only experience and intuition as guides.

TURBINE HELICOPTERS will be in commercial operation in 1961.

ROCKWELL-STANDARD's W. A. JOHNSON doesn't accept the idea of a single lubricant for transmission and rear-axles as an unquestionable MUST. "There is a possibility," he says, "that other important and equally valid aspects may compel us deliberately to consider the opposite approach. . . . The idea should be explored in both directions before either alternative is actually discarded in favor of the other."

To Protect Our ICBM's From Surprise Attack:

Fig. 1 — Silo-lift for Titan missile is designed to operate in high overpressure range against high megaton warhead yield.

·Hard Launching Sites

·Mobility and Dispersion

Based on talk by

W. R. Stumpe and M. V. Kadlick

American Machine & Foundry Co.

THE program to protect our retaliatory ICBM's from a surprise attack before they are launched includes the following techniques:

- Use of hard launching sites (that is, ones designed to withstand a high degree of blast, ground shock, heat, and radiation effects of a nuclear or thermonuclear explosion).
- Design ICBM's so that they are adaptable to mobile launching from air, land, or sea craft.

No one launching technique is necessarily better than another; rather, just as any good team mixes its plays, we need a good mixture of all launching techniques to confuse the enemy.

Today, however, the trend appears to be from soft to hard to harder to hardest to mobility and dispersion.

Discussed here are examples of both hard launching installations and vehicle support systems being studied to provide mobility and dispersion.

Hard launching installations

Atlas Horizontal — Present Atlas bases are above ground. The 75-ft high, 10-ft diameter missile, weighing 243,000 lb is stored horizontally in an unfueled condition. For launching, it is raised to the vertical position by an overhead erector, fueled and fired.

Good design of the sliding roof, erector, and fueling systems achieves the required minimal response time. While not meeting the requirements of a hard

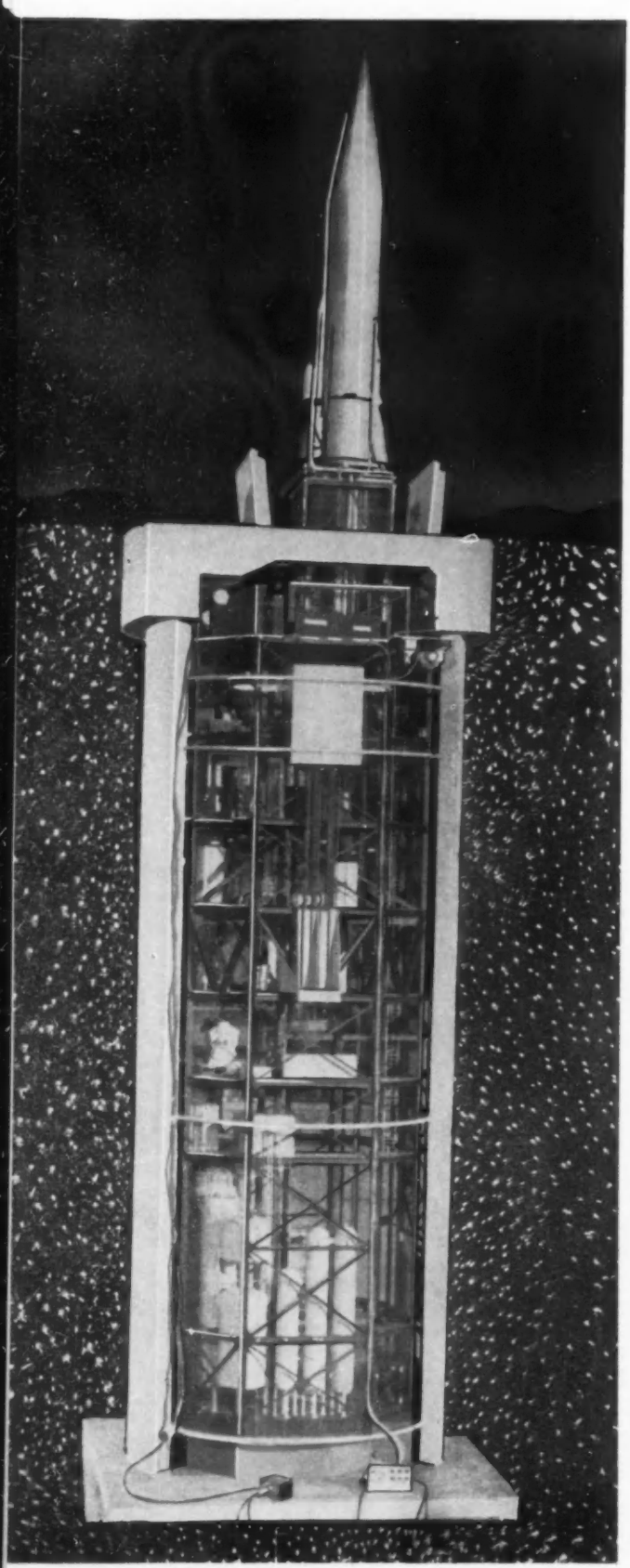


Fig. 2 — Silo-lift for Atlas missile. It is similar to that for Titan, except that there is a single silo rather than three, as for Titan.

ICBM's

. . . continued

site, the unusually large quantities of reinforcing steel used in the concrete construction do provide some blast resistance.

Titan Silo-Lift — Since megaton warhead yields are becoming larger, the enemy can be a considerable distance off-target and still damage the installation. To overcome this deficiency, an underground launcher design is desirable. The missile chosen for this system was the Titan — liquid fueled, like the Atlas. The Titan is 90 ft long, 10 ft in diameter, and weighs 222,000 lb fully fueled. It will be stored, serviced, and launched from completely contained underground installations.

This is the first missile installation that can be justifiably designated as hard, since it is designed to operate in a high overpressure range against a high megaton warhead yield.

In the silo (Fig. 1) the Titan is placed by stages onto the launcher platform, which operates an elevator. When the first stage is loaded above ground, the launcher platform is lowered so the second stage can be installed at ground level, and lastly, the nose cone is similarly installed. The fully assembled missile, when lowered, with the concrete doors closed, is in the hard condition.

In this condition, the missile is isolated by means of a crib structure, which is shock-mounted through a mechanical spring system. Within this crib structure, the missile is raised and lowered on the launcher platform. When the command to launch is received, the crib is locked to the silo walls, the missile is fueled, the doors are opened, and the missile raised to the firing position.

It is obvious that the Titan approaches our initial criteria of installation protection and minimum retaliatory time. It is important, of course, that, in addition to the missile itself, all the ancillary parts of the weapon system have the same hardness capacity.

A missile complex involves three missile silos, 155 ft deep and 40 ft in diameter, three propellant silos 37½ ft in diameter, three equipment silos 50 ft deep and 40 ft in diameter, two antenna silos 65 ft deep and 27 ft in diameter, plus a control center. All these underground installations are interconnected by tunnels 6–10 ft in diameter. Since the complexes are self-contained, they must also be fully air conditioned and provide the necessary living quarters.

Atlas Silo-Lift — In order to improve its survivability, the Atlas is also being installed in an underground launching system similar in concept to the Titan, except that a single silo is used rather than three, as with the Titan (Fig. 2).

Below-Ground Launch — The next logical step is to fire the missile directly from the hole rather than bringing it to the surface (Fig. 3).

With this system, the missile remains in the hard condition for the maximum amount of time prior to launch. In addition, the improved reliability

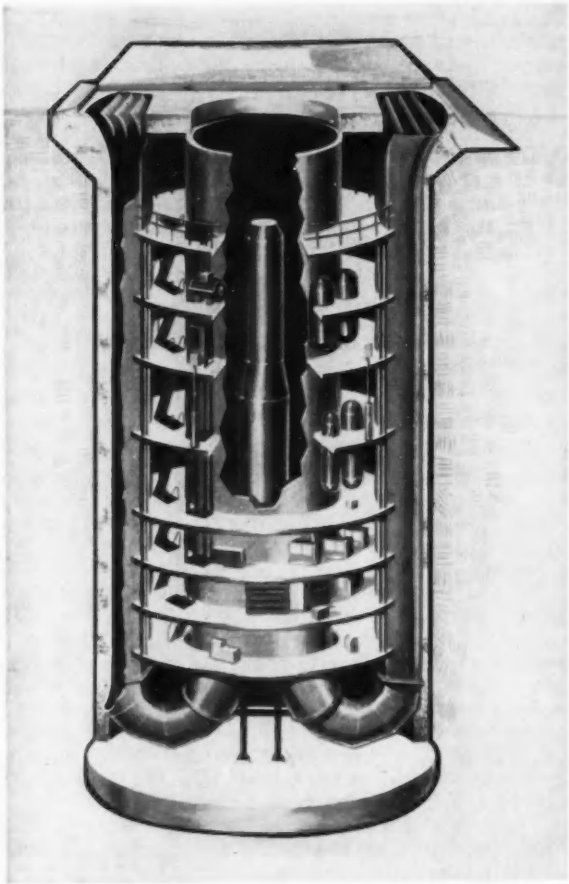


Fig. 3 — Below-ground launch makes it possible to fire missile directly from hole rather than bringing it to surface.

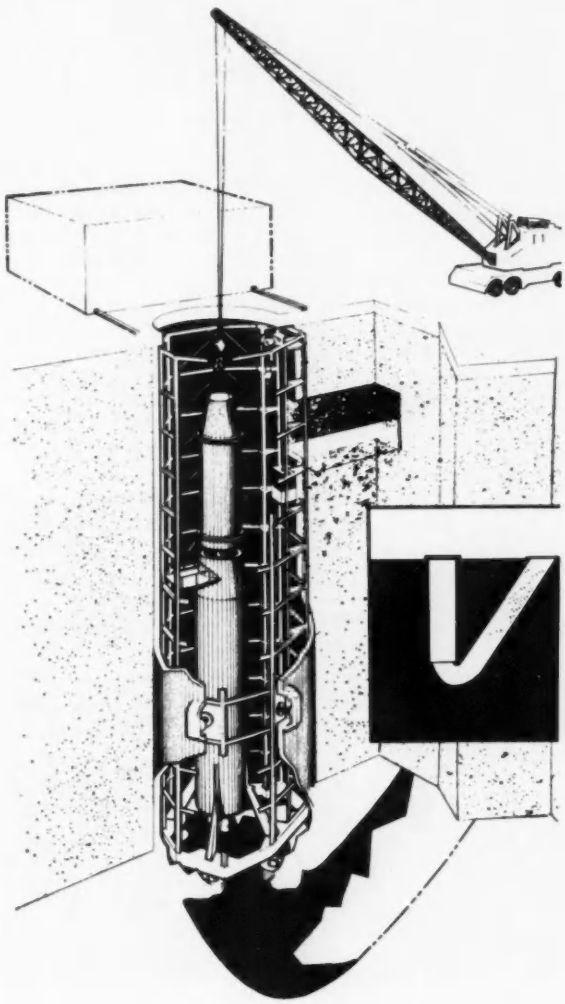


Fig. 4 — Application of below-ground launch is also being studied for Titan.

ICBM's

. . . continued

achieved by eliminating the mechanisms required to bring the missile to the surface is definitely worthwhile.

Minuteman — The Minuteman departs radically from the Atlas and Titan in concept and operation. It was conceived as a relatively inexpensive weapon system. Since it uses solid propellant, it has some definite operational advantages over the liquid-fueled Atlas and Titan. Its warhead capacity is smaller than that of either the Atlas or the Titan, however, and so the need for these ICBM systems for selected targets remains.

The operational concept for the Minuteman is quite simple. Many missiles will be stored in underground silos similar to those for the Titan. Because of the solid propellant, and other system improvements, however, the Minuteman can be stored underground for long periods with minimum service requirements. On the command to launch, doors will be opened and the missile launched directly from its underground position.

Titan Below-Ground Launch — The engineering problems of applying below-ground launch to the Titan are now being studied (Fig. 4). These problems are substantial. There is, for example, the acoustical problem of reducing the contained noise level to a value at which the missile itself is not damaged by the resonances, and the problem of handling the exhaust gases of combustion.

Future of Hardness — Hardness is a relative term depending on the megaton yield and the overpressure. The question really is, "How hard is hard?"

As megaton yields become larger for similar size warheads, are our present hard criteria becoming obsolete? Can the enemy damage our retaliatory capability of using larger megaton warheads within present accuracies, or even with less accuracy? The answer is probably yes. When we talk about the effect of a multimegaton bomb, we mean craters several miles in diameter and about half a mile deep.

The problem of putting in a hard installation against this type of attack is enormous. It can be done through such methods as installations within mountains, or underwater launching sites, but several such installations could easily use up a good portion of the yearly defense budget. In addition, there is already a rising criticism in some quarters against fixed bases as a "Maginot Line" philosophy. For an answer, if fixed bases will not suffice, we must consider mobility and dispersal.

Mobility and dispersal

As the circular probably error of future enemy weapon systems decreases, mobility and dispersion may become essential for the survival of our deterrent missile forces. This requires the adaptation of the missiles themselves to mobility and also the development of mobile launching systems.

Essential characteristic of intercontinental missiles for mobility requirements is that the missile contain a powerplant or thrust package that will permit minimum reaction time for the weapon system. Also, the trend toward more efficient power packages is producing missile configurations and characteristics that are more adaptable to mobile launching than the present liquid-fueled missile. Prepackaged fuel missiles may, however, satisfy the operational requirements for mobility.

There are three types of mobility: air, sea, and land. For air and sea, there are the air-launched ballistic missile being developed by Douglas and the submarine-launched Polaris ballistic missile, by Lockheed.

So far, land mobility has been relatively untouched for ICBM missiles. Recent articles have indicated that the Minuteman is being considered

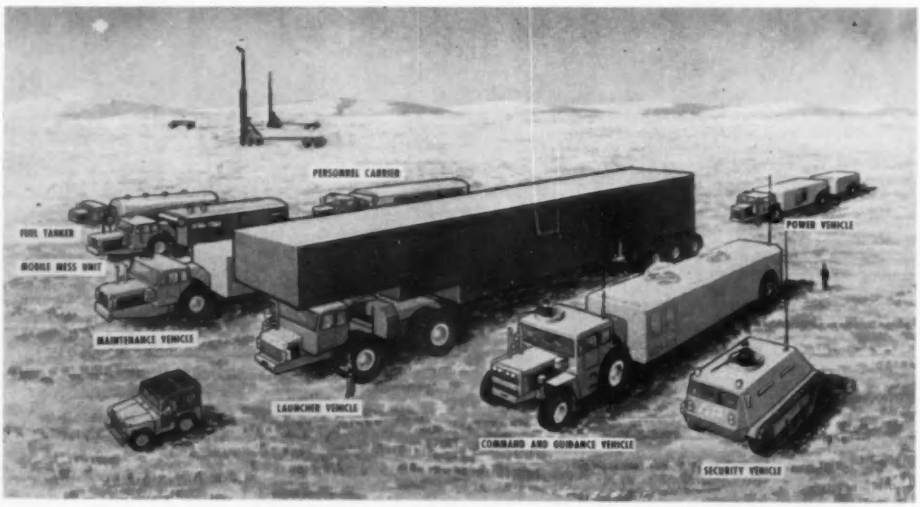


Fig. 5 — Many vehicles — both large and small — are required to provide overland mobility.

for a mobile system to supplement the fixed installation.

There are three basic types of land mobility: vehicular, on improved roads or cross-country; railway, on our vast railroad network; and inland waterways, on our navigable rivers and lakes.

Land Mobility — A large number of vehicles, and many of large size, would be needed to transport ICBM's.

This would make over-the-road travel undesirable, as it would require special escorting, load surveying, and routing. It would, therefore, seem more desirable to use cross-country travel, utilizing the 400 million acres of land still in the public domain. (See Fig. 5.) There are many areas with sparse populations and little or no natural obstacles to impede a convoy of this type. This system might operate by continually rotating between several fixed soft launching sites. It would be difficult, if not impossible, to predict where the missile was at any particular time.

Railway Mobility — Costs for railroad missile support systems may be considerably less than for competing hardbased systems. The operational philosophy would be quite simple. Many missile car complexes would be kept in almost continual motion. Numerous launch areas could be surveyed along railroad right-of-ways. When the launch command is received, the missile car would proceed to the closest launch area and fire the missile. (Figs. 6 and 7).

The problem is that a ballistic missile must be accurately launched if it is to hit a target, hence the need for surveying predetermined launch areas. The simplest way would be to launch the missile directly from the car, although separate launch pads are also a possibility.

Waterway Mobility — The missile system would be contained in a single barge or Great Lakes steamer. It, too, could be kept in continual motion, so that prediction of its location would become difficult. Its prime disadvantage is the slow speed attainable, so that, if spotted and reported, it might still be within the blast zone of an enemy-launched missile.

Integrated Mobility — Mobility with dispersion — "integrated mobility" — may offer an answer to the ultimate hardness problem. It provides a good balance of all types of land mobility, and is based on the premise that specific areas of the country can support more than one type of mobility dispersal technique.

Much land suitable for vehicular overland mobility also comes in contact with the railroad systems and navigable waterways. Here, a higher mobility potential can be achieved if the the techniques are integrated. It may even be feasible to transfer missiles between systems — overland to railroad to overland, for example. The "piggyback" type of operation combines the long haul efficiency of the railroad with the short-haul flexibility of the road vehicle.

The utilization of all mobility approaches involves launchings from railway cars, overland vehicles, inland waterway vessels, ships at sea, submarines, and conventional aircraft. Nuclear-powered aircraft that can stay aloft indefinitely and space platforms will add a new dimension to the mobility area, and then may achieve . . . the ultimate in mobility.

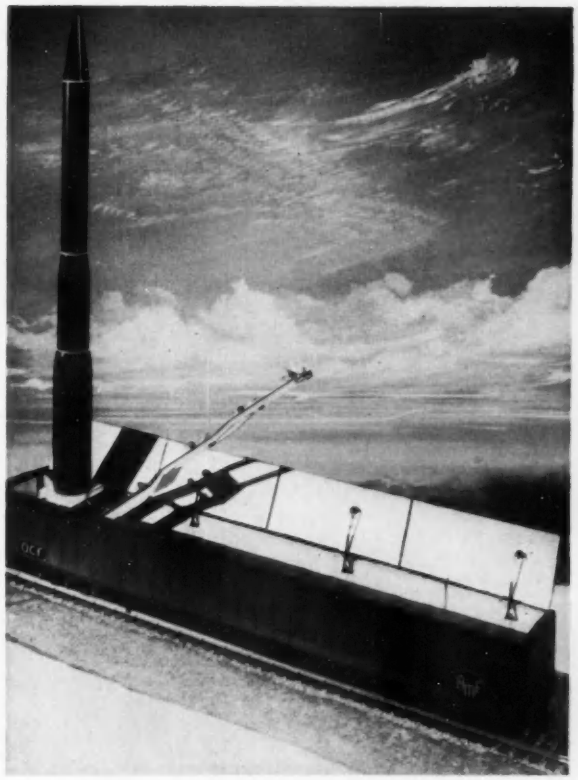


Fig. 6 — Model of railway car missile launching system.

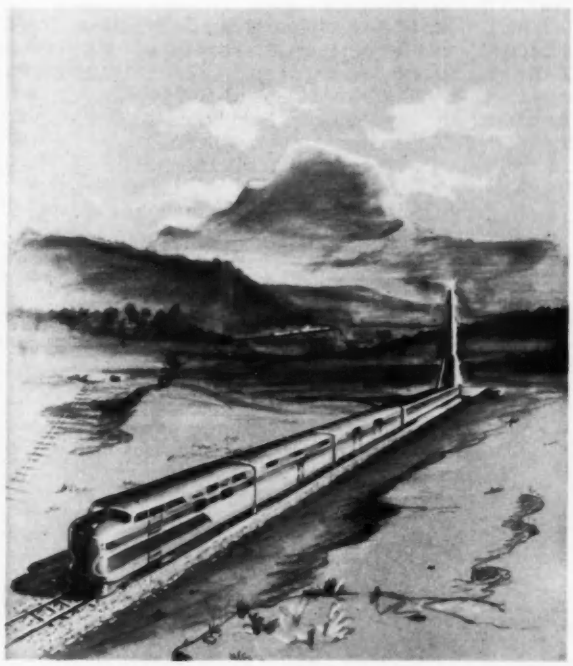


Fig. 7 — Missile car system at launch area, where missile is to be fired.

A quartz piston engine built by GM Research is . . .

A new tool for combustion

Based on paper by **Fred W. Bowditch**
GM Research Laboratories

A NEW RESEARCH TOOL — a quartz piston engine — developed at GM Research (Fig. 1) permits an unobstructed view of the combustion processes occurring in overhead-valve combustion chambers of compression ratios as high as 10.7/1.

This new research engine, as Fig. 2 shows schematically, has a normal overhead valve construction, an elongated piston, and a quartz piston crown. The combustion process is viewed through a slot in the side of the piston by looking at the reflection in a canted mirror stationary inside the piston.

An exploded view of this piston, cylinder, and head assembly is shown in Fig. 3. Changes incorporated as compared to an original experimental design include the laminated disc, the prefocused projection lamps (shown in position around the cylinder), and the additional oil ring in the lower piston section.

A cutaway illustration of the cylinder, piston and head assembly as developed for the final engine is shown in Fig. 4.

The crown of the piston is made of clear, fused quartz. Top and bottom surfaces of the quartz are flat and are polished to provide a transparent piston crown. The final dimensions of the quartz were determined by simultaneous consideration of optical limitations, bonding area requirements, requisite metal wall thickness, and quartz weight.

The upper piston section serves three functions: (1) It provides support for the quartz crown; (2) it seals the combustion chamber from the mirror region by providing two compression rings and one oil control ring; (3) it provides room to permit the stationary mirror to be mounted inside the piston.

This third function is accomplished by making the upper piston section hollow with a slot in one side to permit the mirror to be held stationary while the piston reciprocates about it. The additional two slots in the upper piston section were made to decrease the weight of the piston assembly.

The lower piston section serves two functions: First, it supplies support for the wristpin; second, it provides an oil seal between the mirror region and the crankcase by supplying oil control rings.

The transparent disc, shown in Figure 4, sandwiched between the cylinder and the head was furnished so that external light could be admitted into the combustion chamber. This is often desirable when photographs of the combustion process are taken, since proper external illumination will light up various portions of the combustion chamber, providing location references for interpretation of the photographs.

The cylinder head is of standard overhead-valve design. Since a flat top is furnished on the quartz piston crown, the combustion chamber formed by the piston and cylinder head can be of standard automotive design and, therefore, compression ratio is limited only by the usual problems of valve and spark-plug location. Various cylinder heads are available, providing combustion chambers of from 4.9/1 to 10.7/1 compression ratios.

DATA FOR THIS DESCRIPTIVE ARTICLE were drawn from a paper presented by Author Bowditch in which he discusses in interesting detail the problems met in designing this novel, new research engine.

Included are analyses of the various engineering questions faced, and the specific reasoning behind each of the final design decisions made.

Included also in the paper are high-speed photographs illustrating some of the normal and abnormal combustion studies possible with this new equipment.

Design problems

The most difficult problem in designing this engine was to supply sufficient compressive and tensile strength to the quartz-to-metal seal region of the piston . . . and yet not to obscure the view of the combustion chamber.

To transfer the gas load on the quartz to the upper piston section, a compressive strength of 190,000 psi was assumed for the quartz. Assumed also was a maximum gas pressure of 1000 psi, and a cylinder bore of 3.75 in. With these assumptions, a surface of about 0.070 sq in. is required to carry the load. About 20 times this required area is supplied in the final design by a shoulder on the quartz 0.120 in. wide.

To determine the necessary tensile strength in the quartz-to-metal seal, a maximum tensile force of about 750 lb on the seal due to the momentum of the

research

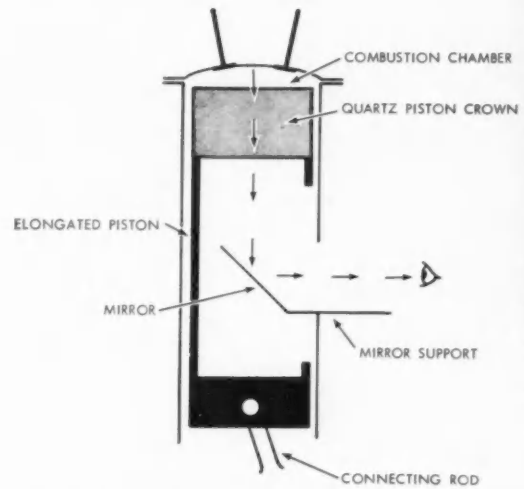


Fig. 2 — Schematic view of new quartz engine, showing a normal overhead valve construction, an elongated piston, and a quartz piston-crown.

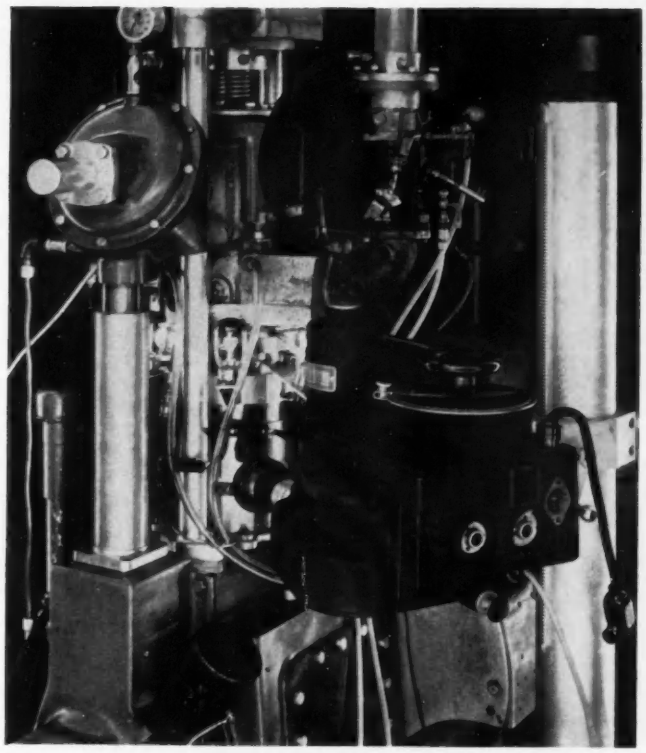


Fig. 1. — This new quartz piston engine enables combustion engine phenomena to be studied in an engine of current combustion-chamber design and at high compression ratios. It makes possible for the first time study of combustion phenomena occurring under road-load as well as full-throttle engine operating conditions.

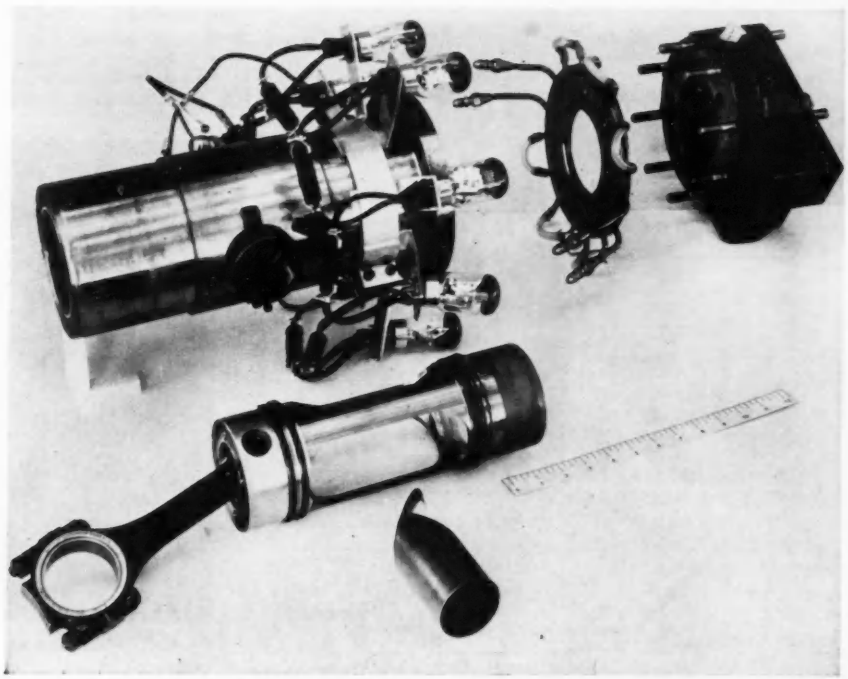


Fig. 3 — Exploded view of assembly of piston, cylinder, and head assembly of new quartz engine.

A new tool for combustion research

. . . continued

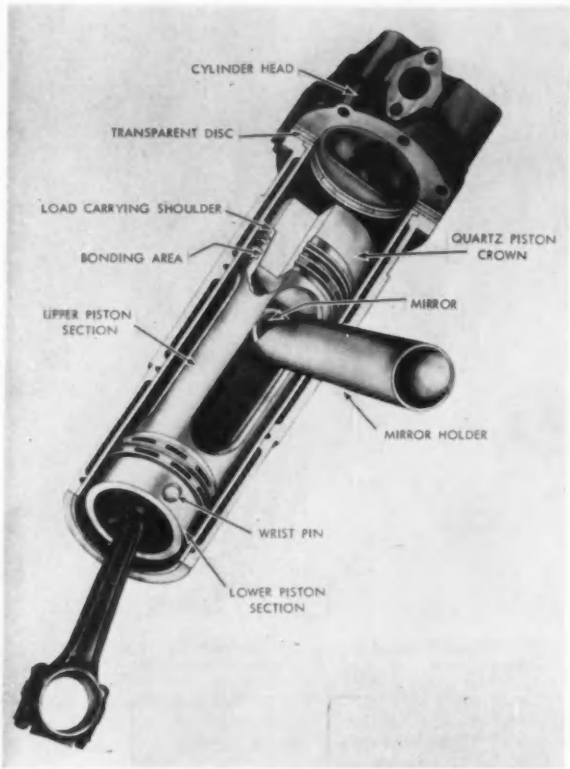


Fig. 4 — Cutaway illustration of the quartz engine's cylinder, piston, and head assembly.

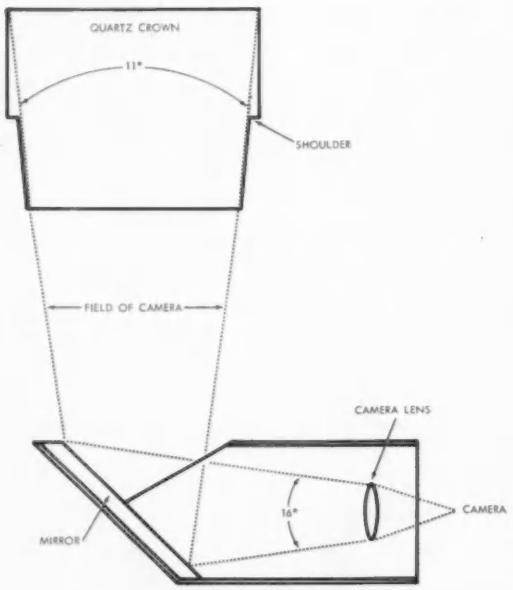


Fig. 5 — Schematic view of optical system of new quartz engine.

quartz crown was used as a basis. The necessary strength is provided in the design by using Shell Chemical Co. Epon 828 to bond the quartz crown to the upper piston section. This provides tensile and shear strengths of 1000 psi at 300 F and about 100 psi at 400 F. (Temperatures in the bonding region are not expected to exceed 400 F.)

To separate the compressive and tensile load-carrying regions — which previous experience indicated desirable — a tapered portion was designed on the bottom of the quartz piston crown (as shown in Fig. 4). The tapered section of the quartz provides 14.5 sq in. of bonding surface . . . which gives a total tensile strength of 1450 lb at 400 F to the quartz-to-metal bond. This is about a 100% safety factor.

The one oil and two compression rings on the upper piston section serve not only to seal the combustion chamber from the mirror region, but also to cool the bonding area.

Fig. 5 is a schematic view of the optical system in this new quartz research engine. Provision was made in the original design to admit external light to the combustion chamber. This was done by making a Pyrex disc the same dimensions as the head gasket, but ¼ in. thick, and including it as a sandwich between the cylinder and head. By directing four 110-v photo spotlights at the disc, sufficient illumination is obtained to light up the major features of the combustion chamber for photographic purposes.

A camera view of the combustion chamber is shown by Fig. 6. The intake valve is in the upper left, the exhaust valve in the lower right, the spark plug in the lower left . . . and the squish, or close-clearance area, in the upper right. The head shown forms a 10.7/1 compression ratio combustion chamber.

This new research engine makes it possible for the first time to study combustion phenomena occurring under road-load as well as under full-throttle engine operating conditions. It may well open a new avenue to gasoline engine combustion research.

To order Paper No. 150B . . .
from which material for this article was drawn, see p. 6.

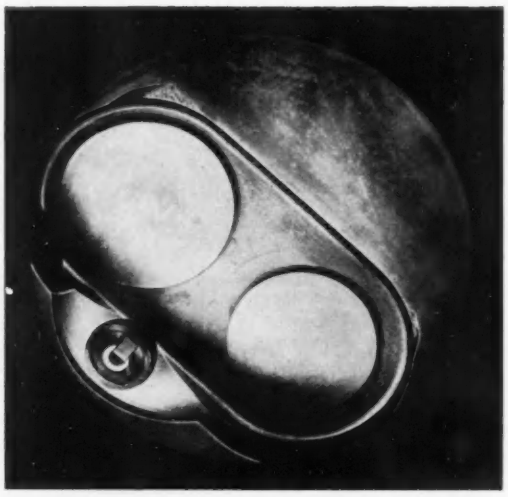
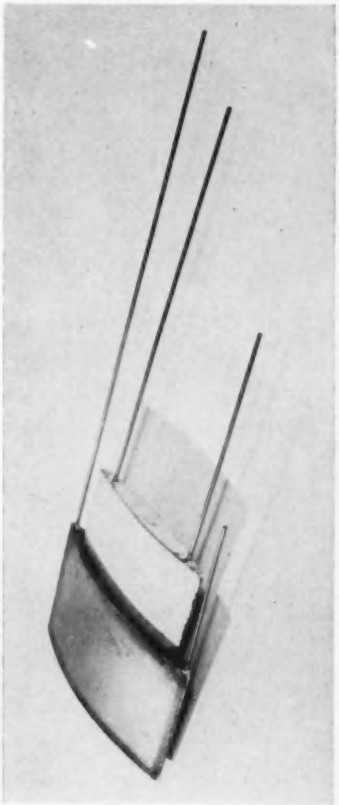


Fig. 6 — Camera view of combustion chamber of new quartz engine.

Hydrocarbon-air fuel cell

can operate motor vehicle economically

But great increase in amp/sq ft is needed for performance; and initial cost is still high.



3.5 w fuel cell

Based on paper by **E. A. DeZubay**
Research Division, Curtiss-Wright Corp.

ONLY ECONOMIC FUEL CELL for motor vehicles is a hydrocarbon-air cell. But current densities (amp/sq ft) must be increased and initial costs reduced to make it practical.

Best chance for early success of this cell lies in the high-temperature, molten carbon cell. The carbonaceous liquid fuel-atmospheric air cell can produce power at a very attractive operating cost — ½ to 4 cents/kwhr (depending on component efficiencies and direct cost of fuel).

At present, the initial cost of hydrocarbon fuel-air cells is high due to the material requirements and fabrication techniques. In contrast, low-initial-cost cells have high operating costs due to their stored oxygen requirements.

Cell design

Curtiss-Wright Research Division has concentrated its research on the molten carbonate cell as the most promising of the hydrocarbon-air cells . . . although other approaches (such as low-temperature and high-pressure operation with suitable catalysts) are possible.

Extensive tests to determine the most suitable electrolyte resulted in selection of a ternary mixture composed of equal weights of sodium carbonate, lithium carbonate, and potassium carbonate. This melts at about 390 C and can be used at much higher temperatures.

Best cell performance is obtained with a fresh electrolyte; however, if carbon dioxide is added to cell air supply, the electrolyte can be used indefinitely with little or no loss in cell performance.

As a result of a materials compatibility study, the following durable materials were recommended for fuel cell construction:

Air electrode case	Silver
Fuel electrode case	Nickel or Inconel
Fuel & air supply tubes	Inconel
Non-critical parts and equipment exposed to the molten electrolyte and/or occasionally to air plus electrolyte vapor	Type 18-8 stainless steel
Ceramic insulators & spacers	Aluminum oxide or magnesium oxide

Electrode design for the experimental cells was an evolutionary process and included fully-welded tubular and oval shapes made entirely of porous metal, rectangular frames with porous metal welded to one or both sides and, currently, flat plate removable electrodes clamped between the two halves of the cell.

The following can be concluded from tests run on fuel cells using propane fuel, porous nickel fuel elec-

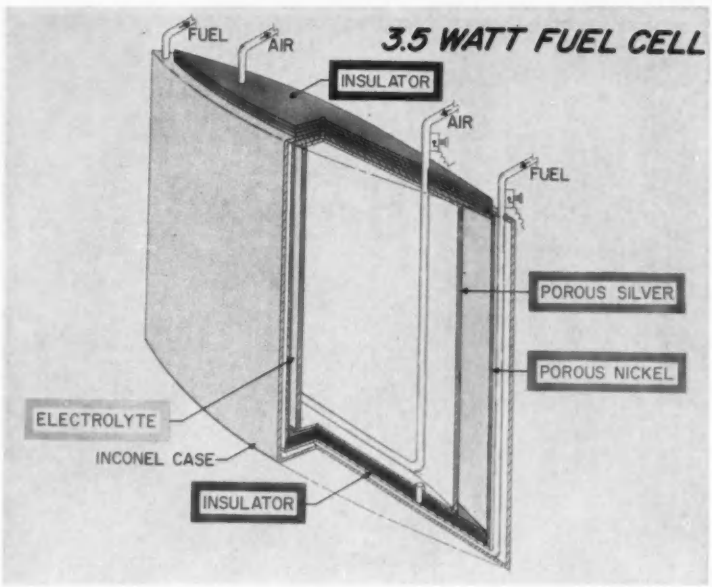


Fig. 1 — Sectional view of 3.5 w fuel cell.

trodes, porous silver air electrodes and ternary carbonate electrolytes:

1. Maximum measured open circuit voltage is 1.02 v.
2. Maximum measured current density is 31 amp/ft² at 0.42 v.
3. Optimum operating temperatures are 500–650 C.
4. Current density varies inversely with the distance between the electrodes.
5. Cell performance is improved by giving the porous nickel fuel electrode an oxidation-reduction treatment prior to use.
6. The high conductivity of the electrolyte precludes the use of series connected cells in a common electrolyte bath.
7. Air flow must be relatively high and a bleed provided to remove the nitrogen and other inert gases.
8. Carbon formation in the fuel side of the cell is a serious problem, if the fuel flow rate to the cell is not controlled carefully.

In order to obtain larger power outputs, a basic cell capable of producing 3.5 w was designed. The design point of this cell was chosen to operate at a current density of 15 amp/ft² at a terminal voltage of 0.65 v. To achieve this, double-sided electrodes of approximately 5 in. × 5 in. were designed. Fig. 1 and top of p. 35 show cell construction and assembly. When assembled, the 3/32-in. space between the electrodes contains the electrolyte . . . a ternary equal-weight mixture of Li_2CO_3, Na_2Co_3, and K_2CO_3. Fuel is propane from a small liquified gas container mounted on the power unit. Atmospheric oxygen is obtained from air.

No performance data is yet available on these cells.

Electric motor car performance

To compare the utilization of two types of fuel cells — the hydrocarbon-air high-temperature cell and the hydrogen-oxygen low-temperature cell — consider a small silent electric motor car. Assume the vehicle has the following fixed components: (1) 20-hp motor and associated switchgear; (2) chassis, wheels, seats, and hardware; (3) body, windshield, and (4) 2 occupants.

To obtain the total weight of the car, weight estimates for each cell, respective reactants and tankage must be made. Table 1 compares these weight estimates and total weight of the car using both cells. It also compares operating costs.

Cell weight — A high-temperature hydrocarbon-air cell using advanced design concepts could have a weight per watt (W_c) of $10/i$ lb per w, where i is current density in amp/sq ft. Corresponding estimate for a hydrogen-oxygen cell is $3.25/i$ lb per w.

Fuel Weight — If an operational requirement of 10 hr is assumed, the fuel weights for both types of cell can be computed.

Since the fuel cell in either example operates at a constant temperature and constant pressure, the maximum energy attainable is the free energy (ΔF). Available free energy of the propane-air reaction (F_c) and the hydrogen-oxygen reaction (F_h) can be calculated:

$$F_c = 6020 \text{ whr/lb } C_3H_8$$
$$F_h = 14{,}850 \text{ whr/lb } H_2$$

However, for every pound of hydrogen consumed in a hydrogen-oxygen cell, 8 lb of oxygen are required so that:

$$F_h = 14{,}850 \text{ whr}/9 \text{ lb of reactants} = 1650 \text{ whr/lb}.$$

The hydrocarbon cell uses air as the oxidizer, so requires no additional reactants.

If 20 hp are delivered at the wheel with a motor efficiency of .85 and a fuel cell efficiency of .70, the energy input to the cells must be

$$E = \frac{20 \text{ hp} \times 746 \text{ w/hp}}{.85 \times .70} = 25{,}100 \text{ w}$$

with an energy output from the fuel cells of

$$E_o = 25{,}100 \times 0.7 = 17{,}550 \text{ w}$$

So for a 10 hr continuous operating requirement, 251,000 whr are required. This yields a fuel weight for the hydrocarbon-air cell of

$$W_{fc} = \frac{251{,}000 \text{ watt-hr}}{6020 \text{ watt-hr/lb}} = 41.8 \text{ lb of propane}$$

and for the hydrogen-oxygen cell of

$$W_{fh} = \frac{251{,}000}{1650} = 153 \text{ lb of reactants total (17 lb hydrogen + 136 lb oxygen)}$$

Tankage Weight — Tankage required for 41.8 lb propane would be 75 lb (based on weight of standard cylinder size No. 1). Tankage weight for gaseous hydrogen and oxygen would be 615 lb based on single tanks for each, with wall thickness one-half that of standard high-pressure cylinders usually used to ship compressed gas.

Gross weight as a function of current density is plotted in Fig. 2. On a weight basis, at current densities less than 150 amp/sq ft the hydrogen-oxygen cell is preferred. From operating cost considerations, the hydrogen-oxygen cell is overshadowed by the hydrocarbon cell.

The importance of light weight is illustrated by Table 2 and Fig. 3 which show the acceleration performance and hill climbing ability respectively of the 20 hp (series-wound) motor vehicle.

As seen in Fig. 2, only a futuristic hydrocarbon-air cell with a current density of about 600 amp/sq ft could be used for a 2000-lb vehicle. The hydrogen-oxygen cell, because of the required tankage weight, misses the possibility of attaining such a low weight.

For a 3500-lb vehicle, a contemporary hydrogen-oxygen cell operating at 60 amp/sq ft would satisfy the required condition. Similarly a hydrocarbon-air cell at 100 amp/sq ft could also meet the weight requirements. . . . This value of current density could be achieved in the near future.

At 5000 lb total vehicle weight, performance is so poor that there would be no demand for such a vehicle, even though both cells could be used as the power source.

To order Paper No. 159E . . .
from which material for this article was drawn, see p. 6.

Table 1 — Car Weight for Two Fuel Cell Types

Cell Type	Hydrocarbon Air	Hydrogen-Oxygen
Motor & associated switchgear	650	650
Chassis	500	500
Body Windshield	220	220
Occupants (2 men)	300	300
Tankage	75	615
Fuel	42	153
Fixed Weight Subtotal	1787	2438
Cell Weight ($17{,}550 \times W_c$)	$\frac{175{,}500}{i}$	$\frac{57{,}000}{i}$
Gross Weight	$1787 + 175{,}500/i$	$2438 + 57{,}000/i$
10 hr cost of operation (max power)	$5.27	$156.60

Table 2 — Acceleration Performance of 20 hp Series Motor at Different Weights

Weight (W)	Time (0 to 30 mph)	Distance (0 to 30 mph)
2000 lb	6.35 sec	205 ft
3500 lb	11.10 sec	359 ft
5000 lb	15.80 sec	512 ft

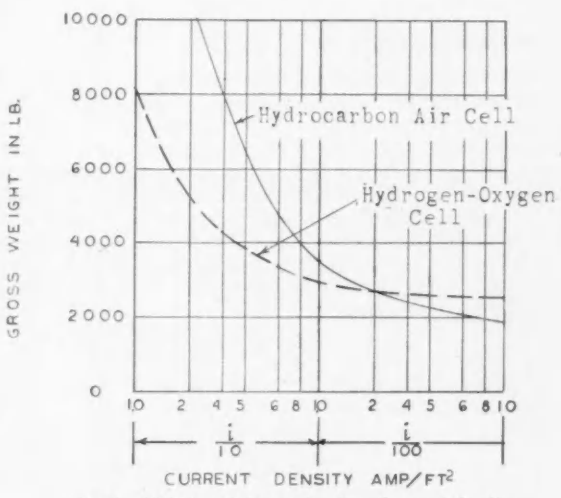


Fig. 2 — Vehicle weight as a function of current density.

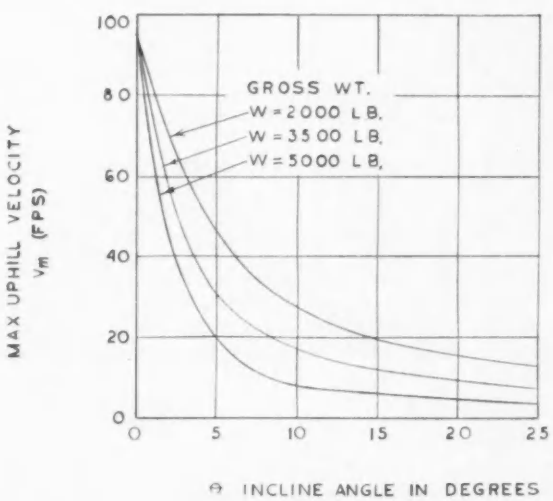


Fig. 3 — Hill-climbing ability of fuel cell car.

Tailoring the Corvair

. . . licks handling problem, thereby gaining had from unconventional

Based on paper by **Charles M. Rubly**
Chevrolet Motor Division, GMC

HANDLING deficiency, caused by a weight distribution of 40% front and 60% rear, was overcome in the Corvair by engineering from the ground up. By giving special attention to tires, to the suspensions and their attachments, and to the relative stiffness of the body, the following four advantages were gained:

- Little change in weight distribution from curb to full load weight.
- Near equal braking effort on weight transfer during braking.
- Light steering effort.
- Increased traction with same overall vehicle weight.

Tire developments

In the early stages of development it was found that existing 13-in. tires were unsatisfactory. After much experimentation it was decided to use a 6.50–13 tire with 4-ply rating incorporating new proportions, a height to width ratio of 0.85, and a lower cord angle. A stiffer carcass stock and softer tread stock were also specified to improve stability and ride comfort. It is used on a 5.5-in. rim with pressures of 15 psi front and 26 psi rear in order to obtain as close as possible equal slip angles under lateral accelerations.

Fig. 1 shows cornering force versus slip angle for three different tire and rim combinations. The difference between lower and upper curves is the total gain when using the new tire section on a 5.5-in. rim, for an average gain of approximately 19%. At the specified tire pressures and at one-passenger load, the deflections of front and rear tires are practically the same. At five-passenger load the difference in deflection is less than 1 in. Under hot conditions the difference will be slightly greater.

Front suspension

The front suspension shown in Fig. 2 was designed for simplicity, ease of assembly, and low cost. The only significant difference from the regular Chevrolet car suspension is the use of a strut rod instead of a double-bushed, lower control arm, and the feature of unitizing the front suspension for ease of assembly at both manufacturing and assembly plants. Camber and caster are preset under a load representing the proper weight of the car on the suspension. Brake adjustment is also accomplished at time of unitizing. Toe is partially set at the manufacturing plant, with the final setting made at the end of the final assembly line with front and rear wheels on the rolls.

The front suspension unit is attached by six bolts, three on each side, driven from below into nuts in the body structure. The front suspension crossmember is attached directly to the body structure without any means of isolation because none has been found to be needed.

Rear suspension

Fig. 3 shows the rear suspension, transaxle, and engine assembled as a unit. This unit is attached to the body by five bolts, all cushioned in rubber.

In this swing-axle, rear suspension the control arms are mounted in a semitrailing attitude so that their projected pivot axes pass through their respective axle shaft universal joint centers. This arrangement limits slip at the U-point splines and allows the use of single, self-aligning, bearing assemblies at each axle shaft. Fig. 4 shows the bearing outer housing to be fastened through the flange plate to the control arm. The bearing inner race is a press fit on the axle shaft which carries the brake drum.

If transaxle and engine are properly shimmed fore and aft, and if up and down dimensions are correct, the centerline through the control arm shaft intersects the U-joint on the inner end of the axle shaft. If such alignment existed at all times, the flange plate, brake shoes, and drum would stay parallel to each other throughout the ride travel. But this is unlikely, so the bearing was designed to accommodate a 3-deg variation between flange plate and drum.

Roll couples

Roll couple distribution front and rear is shown in Fig. 5, where the Corvair with its swing axle is

Suspension

advantages to be

weight distribution

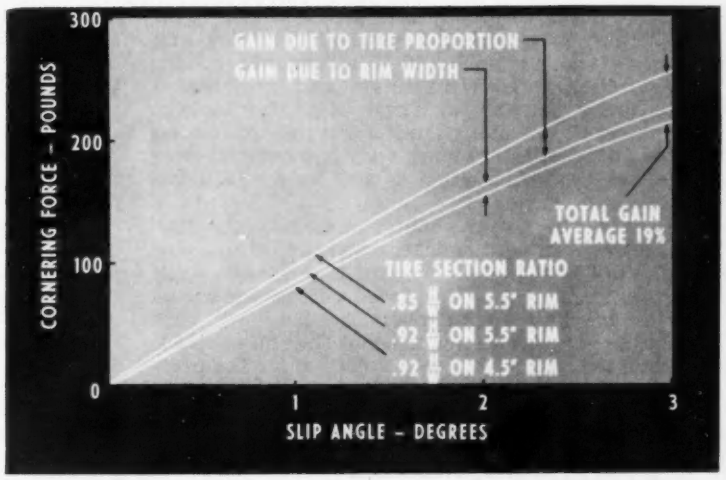


Fig. 1 — Handling deficiency, characteristic of vehicles having a 40–60 front and rear weight distribution, was overcome in the Corvair by using a tire of new construction and proportions, with lower pressure in the front tire. Chart shows gain in cornering force versus slip angle by going to a tire of 0.85-height to width ratio on a 5.5-in. rim.

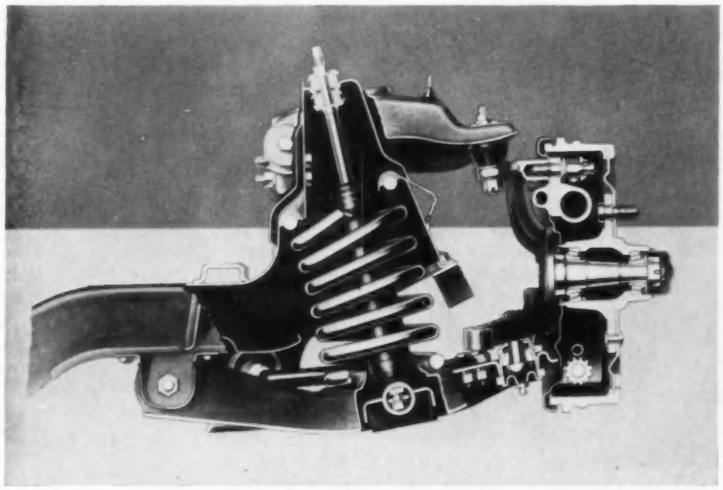


Fig. 2 — Corvair front suspension differs from Chevrolet in use of strut rod in place of double-bushed, lower control arm. Suspension is unitized.

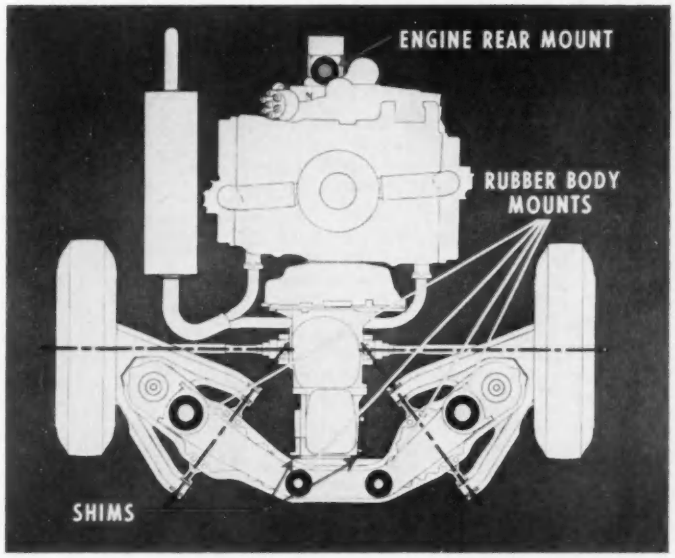


Fig. 3 — Swing-axle rear suspension, transaxle, and engine are assembled as a unit, attached to body by five bolts cushioned in rubber. Note control arm mounted in semitrailing position.

compared with another vehicle identical except for a solid rear axle and leaf springs. The roll axis intersects the centerline of front wheels at the ground in both cases. With the roll axis being higher on the swing axle and the height of c.g. the same in both cases, the moment around the roll axis is less for the swing axle, reducing body roll over the leaf spring suspension as much as 40% under identical lateral accelerations.

However, due to the difference in how the load causing the roll during lateral acceleration is applied to the tires, a greater percentage of roll couple and overturning couple is carried on the leaf spring car than on the swing axle vehicle. Moreover, with this swing axle suspension more of the roll couple is taken on the rear than on the front, and if tire pressures were equal front and rear the result would be greater slip angles on the rear than on the front. Actually, the difference between slip angles under cornering conditions is very small because of the lower front tire pressure made possible by the lighter front end.

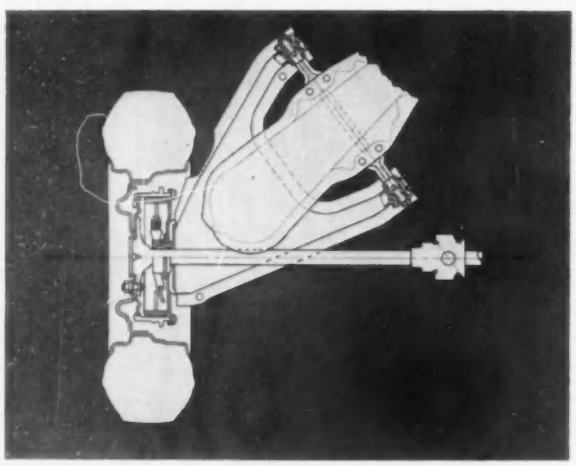


Fig. 4 — Bearing outer housing of Corvair rear suspension is fastened through flange plate to the control arm. Bearing inner race is a press fit on the axle shaft carrying the brake drum.

Why this type of swing axle suspension?

There are swing axle rear suspensions which permit transferring more of the roll couple to the front end. This particular type was chosen because of:

1. Lower cost.
2. Ease of assembly.
3. Ease of service.
4. Simplicity of design.
5. Ability to use coil springs.
6. Reduction of unsprung weight.
7. Ability to isolate the body from distortion stresses. The rear suspension cross-member, isolated from the body by eight large rubber cushions, supports all its suspension elements. This is a large factor in reducing transmission of road and engine noises into the vehicle.

Body structure

With a separate frame and body type of construction, an adequately stiff body can be mounted through rubber to a somewhat more limber chassis frame, thus permitting a torsional rate over the length of the wheelbase as desired for ride without sacrificing body quality.

With integrated frame and body construction the designer's freedom is restricted. The stiffness required for body durability and performance cannot be sacrificed, so that a greater proportion of the flexibility or isolation from the road has to be designed into the suspension or its mounts. In this respect unitized suspension systems have a clear advantage. The Corvair, for example, with the chassis springs blocked out has a unit torsion rate of approximately 60,000 lb-ft/ deg /ft. But the body alone is stiffer. The ability to isolate the rear suspension from the body through rubber cushions permitted the tailoring of torsional rigidity for ride quality without sacrifice of body quality.

To Order Paper No. 143D . . .
from which material for this article was drawn, see p. 6.

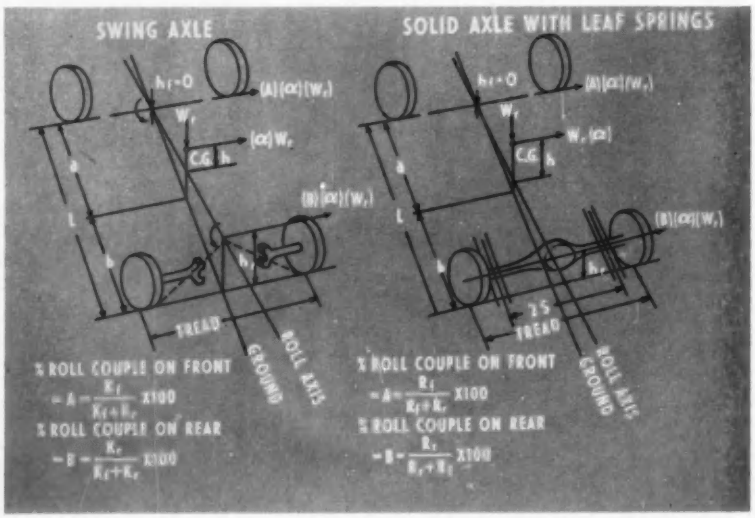


Fig. 5 — Schematic view to show roll couple distribution of Corvair with swing axle and identical car with solid rear axle and leaf spring. Body roll with swing axle is reduced as much as 40% over that of leaf spring under identical lateral accelerations.

Better Air Brakes

are just around the corner

Based on paper by

R. B. Palmer
Ford Motor Co.

THE MODERN airbrake is a vast improvement over that of 30 years ago. But even greater advances lie ahead, both in the foundation brake and in the air supply.

A wedge-operated brake, on which considerable work has been done already, is among the more interesting designs soon likely to come into general use. The British Fawick-Girling design — one of several currently under development here and abroad — uses one chamber mounted at a right angle to the brake which, by a system of bell cranks and levers, results in two primary shoes per brake, thus increasing the effectiveness approximately 50%. This brake is now in use on some British vehicles.

New retarder brake

There are other types of brakes employing wedges at top and bottom, each of which is actuated by a separate air chamber and each having the same 50% increase in effectiveness as the Girling brake. Wedge-operated brakes installed on several Greyhound cross-country buses some years ago are still working satisfactorily as far as is known.

Brake manufacturers keep their developments under wraps, but it is known that the Wagner Electric Co. has under development a new type of foundation brake which can double as a retarder. This development was sparked by the realization that in view of higher speeds and loads the drum-type brake has just about reached the limits of capacity because of space limitations. The Wagner design is a disc brake, air operated and liquid cooled. Since the specific heat of the liquid is about six times that of iron, this type of brake obviously can dissipate large amounts of heat. As a result, the wear of linings would be very low and fade would be reduced to a minimum. For this reason, the brake also can be used as a retarder.

Most retarders in use today, other than exhaust retarders, are very heavy and they are not received with any enthusiasm because payload is such an important factor in commercial vehicles. For this reason, the liquid-cooled brake has definite promise for the future.

Trend to higher pressures

There is a distinct trend toward higher air and tank pressures. The old governor setting of 85 psi cut-in and 105 psi cut-out has been increased to 105 psi cut-in and 125 psi cut-out by at least three truck manufacturers. A 185-psi safety valve would be required to maintain the 50% overload requirement on the valve. There is a trend toward still higher tank pressures, ranging from 350 to 500 psi. These higher pressure systems would permit use of smaller actuating units which would be all to the good in view of the space limitations in the foundation brake area.

Nevertheless, the use of higher pressures would create a large number of problems. Some new types of fittings and much better hose would be required. Tanks would be of heavier gage and probably would be required to pass ASME tests as unfired pressure vessels. We can also look for a split system which would always provide brakes on at least one axle of a single vehicle and on two or more axles of a combination.

To Order Paper No. 184B . . .
from which material for this article was drawn, see p. 6.

Flexible Reentry Glider

for bringing astronaut to earth unscorched

Based on paper by

J. G. Lowry and F. M. Rogallo
NASA Langley Research Center

A PROMISING contender among reentry vehicles under investigation by the NASA for aeronautic and space flight application is the flexible glider shown in Fig. 1.

In this artist's conception, the passenger and cargo compartment is suspended on lines beneath the flexible aerodynamic surface, which is essentially a tension structure of very light weight per unit of area. This lifting surface would be kept folded in a bundle like a parachute until deployed for reentry.

Why a lifting vehicle?

The reasons for choosing a lifting type of reentry vehicle are illustrated in Fig. 2. Two flights paths are plotted to show the difference between the lifting and nonlifting (capsule) type of reentry. The lifting vehicle flies at lower speeds at the higher altitudes and keeps out of the region of high heating. This reduces the problems associated with high-temperature materials as well as those concerned with keeping the astronaut within tolerable heat limits. The lower the wing loading the further the lifting vehicle curve is from the heat boundary and thus the cooler the structure. For this reason, the vehicle being discussed here has as low a wing loading as possible. Other advantages are the reduction in reentry accelerations and the ability to maneuver laterally as well as in the plane of the orbit.

Results of tests

Models having 7- and 17-ft spans have been built and tested in a wind tunnel as well as given free-glide tests from helicopters. A model was constructed of thin (1/64-in.) sheet aluminum and was restrained along the keel and at the confluence of the shroud lines. Its performance encouraged the construction of a model with a flexible surface, nylon sealed with ¼-mm Mylar, and rigid leading edges and keel. Rigid members were used because they simulated inflated edges without the trouble of building inflated structures.

One model was built with the spring-loaded nose section turned up (Fig. 3) and another with the nose section turned down. The turned-up nose gives much lower lift-drag ratios than the turned-down nose, but it acts to make the glider very stable in free glides and takes care of unusual launch attitudes and severe gusts. A full-scale device is envisioned which would have an almost straight nose section since it would be controlled by pilot or by radio control at all times.

To evaluate the flexible lifting surface, calculations were made using equations involving 2 deg of freedom over a curved earth. The reentry into the earth's atmosphere was at a constant angle of attack 60 deg, and an entry angle of 1 deg to the local earth tangent. It was found that the velocity fell rapidly while the vehicle was still at extremely high altitudes and as a result the maximum temperatures are reasonably low — within the capabilities of existing materials.

Retro-rocket requirements

For near earth orbits the high drag of the lightly loaded vehicle at angles of attack approaching 90 deg can provide a retarding force to help initiate reentry, thereby reducing retro-rocket requirements. Fig. 4 shows the area where retro-thrust would be required as a function of the orbital altitude and the distance along the earth traveled. The cut-off point could be anything from say ¼ to 1 or 2 orbits and the altitude would depend upon the size of the flexible surface relative to the total weight. The surface could be made large enough so that no retro would be required for some orbits. Assuming this has been done, it is only necessary to open the lifting surface and glide to the earth.

To Order Paper No. 175C . . .
from which material for this article was drawn, see p. 6.

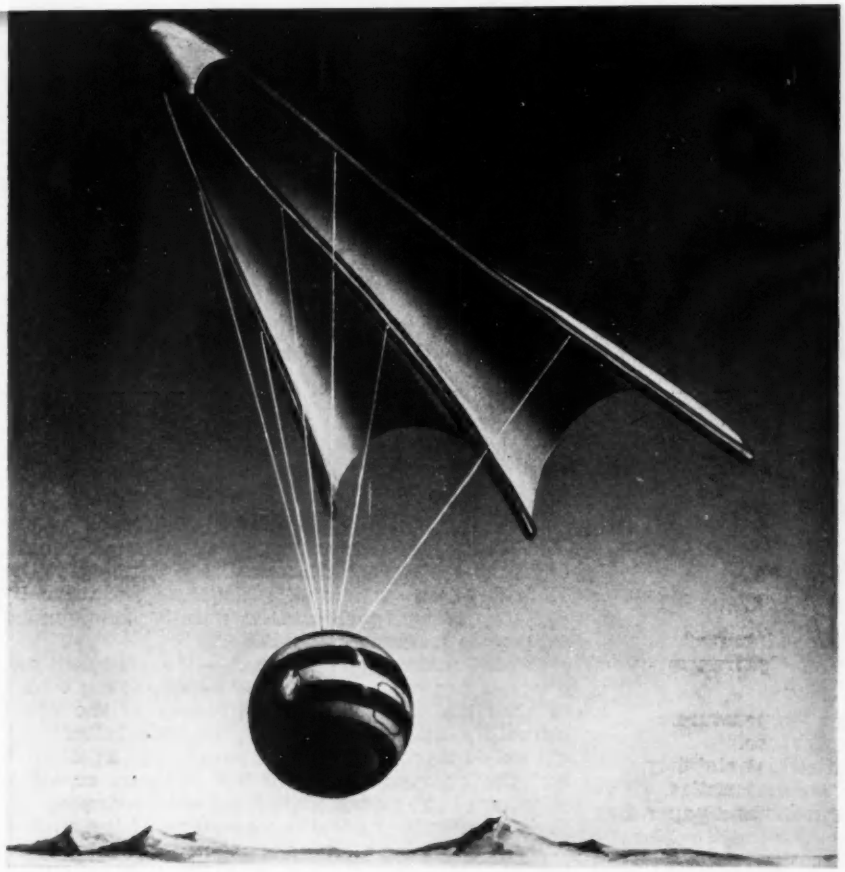


Fig. 1 — **Pictorial conception of a flexible reentry vehicle.** The passenger and cargo compartment hangs from the flexible surface.

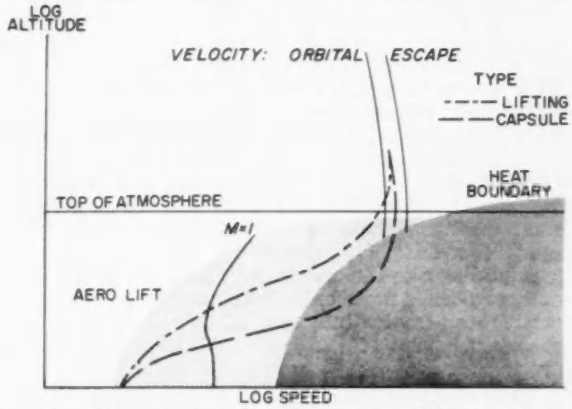


Fig. 2 — **Reentry paths for lifting and nonlifting vehicles.** The lifting type enables the astronaut to keep away from the region of high heat.

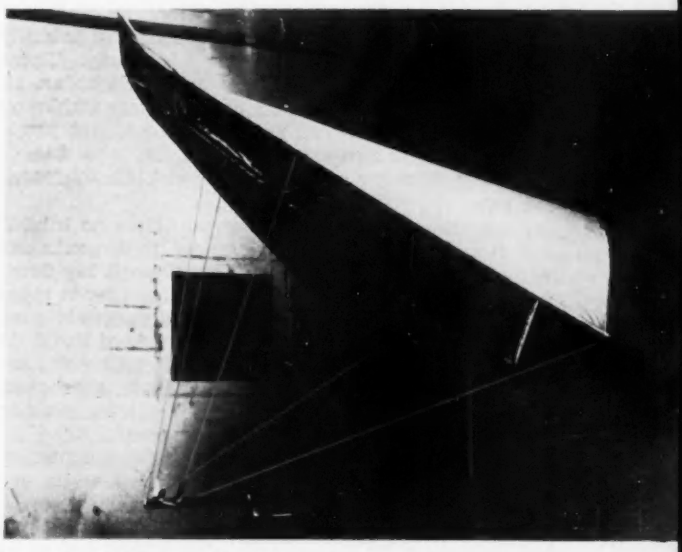


Fig. 3 — **Glider model** with spring-loaded nose section turned up. Turning up the nose section gives much lower lift-drag ratios than when nose is turned down.

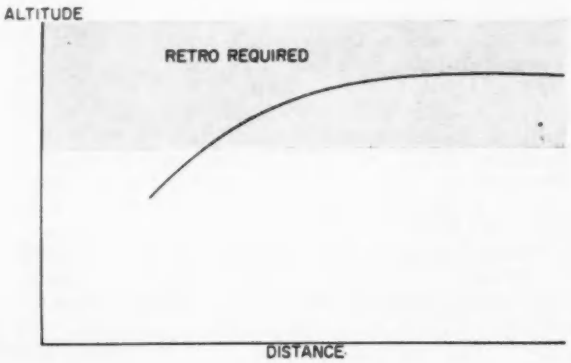


Fig. 4 — **Area where retro-thrust would be required** as a function of the orbital altitude and the distance traveled along the earth.

New Developments in

Automatic Transmission

Based on paper* by

L. W. Manley and N. V. Messina

Socony Mobil Oil Co.

FLUID PROPERTIES of principal importance to proper functioning of automatic transmissions are:

1. Adequate viscosity at high temperature.
2. Good fluidity at low temperature.
3. Excellent oxidation and thermal stability.
4. Proper friction-reducing characteristics.
5. Compatibility with rubber seals and paper disc clutch plates.
6. Good resistance to foaming.

To get these properties, selected base stock and additive combinations must be used.

Additives which inhibit oxidation in a severe 100-hr Hydramatic inertia cycling test may actually deteriorate, as the data in Table 1 indicate. These data show that inhibitors may be added to an oil to decrease oil deterioration under severe oxidizing conditions. If, however, the inhibitor is not properly selected, it can contribute to deposits due to thermal instability under prolonged high-temperature use.

In addition to having proper additives to inhibit oxidation, Socony Mobil tests show, detergents are needed in the formulation to keep deposit lay down to a minimum. Selection of these detergents must be carefully made, because some detergents may interfere with other desirable properties of the fluid — such as friction-reducing characteristics or low-temperature fluidity. Some detergents, moreover, are not too efficient in keeping the transmission clean. The data in Table 2 illustrate this.

As might be expected, automatic transmission fluid composition is an important factor in determining its friction-modifying characteristics. A satisfactory fluid contains a critical balance of additive ingredients in order to obtain just the right amount of "lubricity." Materials used to impart the desired friction-modifying characteristic to an automatic transmission fluid are usually classified as mild, extreme-pressure, or load-carrying agents. Typical of compounds that perform this function are organic polar compounds such as sulfurized fats, fatty acids, and esters.

Concentration of the additive employed is extremely critical with respect to balancing the fluid's "lubricity." Table 3 gives results of a study of the "lubricity" effect of an "antisquawk" additive by varying its concentration in a fully compounded automatic transmission fluid.

Table 3 makes apparent that — if insufficient additive is present, as in blend 1 — squawking occurs in the road test but is satisfactory in the 50-hr durability and cycling test. In this latter test, clutch engagement was not as smooth as desired, but the oil completed the test without excessive slipping of the clutch plates and accompanying delayed-shift pattern and overspeeding of the engine.

However, if the additive concentration is too high, as in blend 3, the frictional characteristics are such as to prevent squawking in the road test but are unsatisfactory in the 50-hr durability and cycling test. In this case, during clutch engagements the high concentration of the additive imparts too much "lubricity." This allows clutch slippage, with resultant prolonged shift patterns, engine overspeeding, and clutch-plate burning. The critical concentration effect is, therefore, evident, since in the satisfactorily balanced fluid (blend 2) there is only a small effective concentration range for the "antisquawk" agent.

In addition to the concentration effect, it has been observed that fluid oxidation can destroy the effectiveness of the lubricity additive. This can be observed in the 100-hr jetaway hydramatic inertia cycling test.

Table 4 summarizes the frictional studies made on four fully compounded automatic transmission fluids. It can be seen that in test oils 1 and 2, the road tests indicate satisfactory frictional qualities, but when evaluated in the 100-hr Hydramatic inertia cycling test, squawking occurs. In each case the fluids showed a substantial neutralization number increase, indicating oil oxidation. However, in the 100-hr test with test oils 3 and 4 no squawking occurs, and the fluid does not oxidize, as evidenced by the lack of acid formation.

One final factor that should be considered with respect to the frictional qualities of a fluid is the possible interference of various additives in the formulation. This effect is summarized in Table 5, which gives the squawk ratings obtained in a test car with different additives.

It can be seen that lubricity agent A possesses good antisquawk properties and that detergent B also shows improved antisquawk properties over the

* The paper from which the material for this article was drawn was presented at the 8th International Automobile Technical Congress at The Hague. The Congress is sponsored by Federation Internationale des Societes d'Ingenieurs des Techniques de l'Automobile (FISITA).

Fluids

Table 1 — High-Temperature Transmission Tests

	Powerglide Oxidation Test Rating	100-Hr Cycling Inertia Test Rating
Test Oil I[a]	Excellent[b] (very clean)	Excessive oil oxidation at 60 hr
Test Oil I plus Inhibitor A	Borderline[b] (slight deposits)	Good oil condition at 100 hr
Test Oil I plus Inhibitor B	Excellent[b] (very clean)	Moderate oil oxidation at 90 hr
Test Oil I plus Inhibitor C	Excellent[b] (very clean)	Good oil condition at 100 hr

[a] Contains V.I. improver, detergent, inhibitor, and antisquawk agents.
[b] Duplicate test runs.

base oil, although still unsatisfactory. However, contrary to what might be expected, combining detergent B with lubricity agent A (line 4) results in squawking, indicating the incompatibility of the two materials. However, as indicated by the satisfactory squawk test, detergent F does not interfere with the effectiveness of lubricity agent A. Therefore, it is apparent that, in choosing additives for an automatic transmission fluid, many things must be considered.

Other properties

In addition to the major performance characteristics, several other properties must be incorporated in a satisfactory automatic transmission fluid. Principal of these are:

- The fluid's compatibility with system components.
- Its resistance to foaming.
- Its rust prevention ability.

The main elements to be considered with respect to fluid compatibility with system components are:

1. Clutch plate facing material.
2. Nonferrous transmission components.
3. Elastomeric seals.

Fluid incompatibility with clutch plate facing materials has been observed in laboratory transmission cycling tests, which show deterioration and removal of some facing materials from their steel backing plate. If this distress becomes severe enough, transmission malfunctioning will result.

In some cases clutch plate distress can be at-

Table 2 — Effect of Detergent Type on Powerglide Oxidation Test

Test Oil (without Detergent)	% Detergent Metal in Oil	Powerglide Oxidation Test
Plus Detergent Combination A	0.4	Excellent (very clean)
Plus Detergent Combination B	0.4	Light deposits

Although both oils contain the same amount of metallic detergent on a metal equivalent basis, the results in the Powerglide test are quite different.

Table 3 — Concentration Effect of "Antisquawk" Agent on Fluid Lubricity

	Blend 1	Blend 2	Blend 3
% "Antisquawk" Agent	1.6	2.1	3.2
Squawk Test — Test Car	Occasional squawk	None	None
50-Hr Durability and Cycling Test	Pass	Pass	Rear clutch slippage at 37 hr

Table 4 — Effect of Oxidation on Friction Modifying Characteristics of Automatic Transmission Fluid

Test Oil	1	2	3	4
Car Test	Smooth shift, no squawk	Rough shift, no squawk	Smooth shift, no squawk	Smooth shift, no squawk
100-Hr Inertia Cycling Test	Squawk at 60 hr	Squawk at 90 hr	No squawk	No squawk
Neut. No. Increase at Time of Squawk	8.9	1.7	Nil	Nil

Table 5 — Effect of Additives on Frictional Qualities of Automatic Transmission Fluids

Oil Tested	Squawk Ratings in Test Car
1. Base oil	Heavy
2. Lubricity Agent A[a]	None
3. Detergent B[a]	Light
4. Lubricity Agent A[a] + Detergent B[a]	Medium/heavy
5. Lubricity Agent A[a] + Detergent F	None

[a] Same concentration of lubricity and detergent additives in all blends.

Table 6 — Effect of Additives in 5000-Cycle Powerglide Test

Additives in Finished Fluid	Result
Antioxident A	Fail — plates flaked
Antioxidant B	Pass — no distress
Antisquawk Agent A	Fail — plates flaked
Antisquawk Agent B	Pass — no distress

New Developments in

Automatic Transmission

Based on paper* by

L. W. Manley and N. V. Messina

Socony Mobil Oil Co.

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In addition to having proper additives to inhibit oxidation, Socony Mobil tests show, detergents are needed in the formulation to keep deposit lay down to a minimum. Selection of these detergents must be carefully made, because some detergents may interfere with other desirable properties of the fluid — such as friction-reducing characteristics or low-temperature fluidity. Some detergents, moreover, are not too efficient in keeping the transmission clean. The data in Table 2 illustrate this.

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In addition to the concentration effect, it has been observed that fluid oxidation can destroy the effectiveness of the lubricity additive. This can be observed in the 100-hr jetaway hydramatic inertia cycling test.

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Test Oil I[a]	Excellent[b] (very clean)	Excessive oil oxidation at 60 hr
Test Oil I plus Inhibitor A	Borderline[b] (slight deposits)	Good oil condition at 100 hr
Test Oil I plus Inhibitor B	Excellent[b] (very clean)	Moderate oil oxidation at 90 hr
Test Oil I plus Inhibitor C	Excellent[b] (very clean)	Good oil condition at 100 hr

[a] Contains V.I. improver, detergent, inhibitor, and antisquawk agents.
[b] Duplicate test runs.

base oil, although still unsatisfactory. However, contrary to what might be expected, combining detergent B with lubricity agent A (line 4) results in squawking, indicating the incompatibility of the two materials. However, as indicated by the satisfactory squawk test, detergent F does not interfere with the effectiveness of lubricity agent A. Therefore, it is apparent that, in choosing additives for an automatic transmission fluid, many things must be considered.

Other properties

In addition to the major performance characteristics, several other properties must be incorporated in a satisfactory automatic transmission fluid. Principal of these are:

- The fluid's compatibility with system components.
- Its resistance to foaming.
- Its rust prevention ability.

The main elements to be considered with respect to fluid compatibility with system components are:

1. Clutch plate facing material.
2. Nonferrous transmission components.
3. Elastomeric seals.

Fluid incompatibility with clutch plate facing materials has been observed in laboratory transmission cycling tests, which show deterioration and removal of some facing materials from their steel backing plate. If this distress becomes severe enough, transmission malfunctioning will result.

In some cases clutch plate distress can be at-

Table 2 — Effect of Detergent Type on Powerglide Oxidation Test

Test Oil (without Detergent)	% Detergent Metal in Oil	Powerglide Oxidation Test
Plus Detergent Combination A	0.4	Excellent (very clean)
Plus Detergent Combination B	0.4	Light deposits

Although both oils contain the same amount of metallic detergent on a metal equivalent basis, the results in the Powerglide test are quite different.

Table 3 — Concentration Effect of "Antisquawk" Agent on Fluid Lubricity

	Blend 1	Blend 2	Blend 3
% "Antisquawk" Agent	1.6	2.1	3.2
Squawk Test — Test Car	Occasional squawk	None	None
50-Hr Durability and Cycling Test	Pass	Pass	Rear clutch slippage at 37 hr

Table 4 — Effect of Oxidation on Friction Modifying Characteristics of Automatic Transmission Fluid

Test Oil	1	2	3	4
Car Test	Smooth shift, no squawk	Rough shift, no squawk	Smooth shift, no squawk	Smooth shift, no squawk
100-Hr Inertia Cycling Test	Squawk at 60 hr	Squawk at 90 hr	No squawk	No squawk
Neut. No. Increase at Time of Squawk	8.9	1.7	Nil	Nil

Table 5 — Effect of Additives on Frictional Qualities of Automatic Transmission Fluids

Oil Tested	Squawk Ratings in Test Car
1. Base oil	Heavy
2. Lubricity Agent *A*[a]	None
3. Detergent *B*[a]	Light
4. Lubricity Agent *A*[a] + Detergent *B*[a]	Medium/heavy
5. Lubricity Agent *A*[a] + Detergent *F*	None

[a] Same concentration of lubricity and detergent additives in all blends.

Table 6 — Effect of Additives in 5000-Cycle Powerglide Test

Additives in Finished Fluid	Result
Antioxident A	Fail — plates flaked
Antioxidant B	Pass — no distress
Antisquawk Agent A	Fail — plates flaked
Antisquawk Agent B	Pass — no distress

tributed to the additive combination employed in the fluid. Typical results obtained in the 5000-cycle Powerglide test, which gives this distress, are shown in Table 6. (A description of this test is given in the proposed GM Type A Specification.)

Table 6 makes it evident that choice of additives can affect the clutch plate facing durability. This distress appears to be caused by chemical reaction of the additive with the components in the facing material or by clutch plate slippage with fluids having too much "lubricity."

At the same time the chemical reactivity of additive materials should be considered with respect to possible corrosive attack on nonferrous metal transmission parts. This is particularly true of transmissions containing copper-alloy components, which in some instances are corroded by active chemicals. In designing the automatic transmission fluid, the detergent, antioxidant, and the antiwear or lubricity agents should be carefully chosen to avoid corrosive attack.

Fluid leakage in an automatic transmission can become a severe problem if the automatic transmission fluid is not compatible with the elastomer sealing materials. The fluid should not cause shrinking, excessive swelling or cracking of the seals. For optimum performance, a slight swelling (1–6 vol %) in a laboratory-immersion-type test is desired. The type of base oil used is the most important formulation variable affecting seals. In general, the paraffinic stocks shrink the synthetic rubber seals while the naphthenic stocks cause swelling. The level of swell desired may be obtained by balancing the ratio of base oil components consistent with other fluid requirements. Although base oil choice is of most importance, additives may also affect seals.

Automatic transmission fluids must possess excellent resistance to foaming. Usually this can be obtained by careful selection of fluid components plus the addition of antifoam agent, such as the silicon type.

Finally, since the transmission can breathe, water vapor can condense in it. This water can cause rusting, which obviously is undesirable, particularly in close-fitting parts. Rust protection is usually obtained by proper selection of additives . . . . and metallic detergents help greatly in this respect.

Conclusions

From a design standpoint, it is desirable to use a common fluid for both rear-axle drive and automatic transmission. This means that the fluid must meet the requirements for automatic transmissions and must also possess extreme-pressure properties sufficient to lubricate a hypoid gear axle.

This indeed is a difficult problem, because extreme-pressure materials usually degrade thermal and oxidation stability and may adversely react with transmission components, such as clutch-plate facings, nonferrous metals, and plastic parts.

To date, no entirely satisfactory fluid is available — and seals must be used to separate the transmission and axle lubricants. It is the strong conviction of the authors, however, that this problem — like many in the past — will be resolved by the cooperative research efforts of the automotive and petroleum industries.

NUCLEAR best

• Turboprop engine.

Based on paper by

D. P. Lalor and W. C. Schmill

Douglas Aircraft Co., Inc.

PRODUCTIVITY (or rate of doing work per unit of weight invested) of nuclear-powered aircraft is affected by three important parameters (engine type, speed, and cruise altitude) in the following manner:

- Aircraft powered by turboprop engines are more productive than those powered by turbofans or turbojets.
- Maximum productivity (per megawatt) is reached at about 0.55 Mach number. This speed does not change with engine type, although it does vary somewhat with changes in aircraft characteristics.
- Increases in cruise altitude for a nuclear-powered aircraft result in sharp decreases in productivity.

(The term "productivity" — payload times speed divided by take-off gross weight minus payload — is used instead of direct operating cost because of the lack of cost data for nuclear propulsion systems. If direct operating cost had been used as the evaluation criterion, the relative differences between aircraft with different types of engines would have been decreased.)

In this evaluation it was assumed that a unit shielded reactor (all shielding around the reactor, none at the crew compartment) was used that has an operating temperature compatible with long life. The crew dose rate assumed permits crew utilization consistent with present aircraft transport systems.

Effect of engine type and cruise speed

Fig. 1 shows the effect of engine type and cruise speed on relative productivity per megawatt. Note that productivity is divided by the reactor power re-

AIRCRAFT attain productivity with . . .

• Cruise speed of 0.55 Mach number. • Low cruise altitude.

quired for each type of engine at each design point and then normalized to the highest productivity per megawatt. The largest value is at 0.55 Mach number for the turboprop-powered aircraft.

Effect of cruise altitude

Fig. 2 shows the effect of design cruise altitude on relative productivity per megawatt. The data are based on maximum productivity values obtained at each altitude for each engine type. The data were normalized to the turboprop engine at 25,000-ft cruise altitude. Contrary to results obtained with chemical aircraft showing optimum cruise altitudes, the productivity of nuclear aircraft decreases with increase in design altitude. Chemical burning systems show a decrease in both specific fuel consumption and thrust with increasing altitude, thereby arriving at optimum altitudes for operation. The principal effect of altitude on nuclear powerplants is a reduction in thrust for a fixed size of powerplant. The change in reactor shield assembly weight caused by the effect of reduced air density on scattered radiation reaching the crew compartment is a second-order effect. In fact, this effect is more than offset by the increase in powerplant weight and aircraft size needed to fly a fixed payload at the higher altitudes.

The decrease in productivity caused by an increase in altitude from 25,000 ft to 35,000 ft is about 25%. Because of this large degradation in productivity with altitude, nuclear aircraft should be designed for operation at the lowest practical altitude. For a multipurpose nuclear aircraft, altitudes of 20,000–25,000 ft represent an acceptable compromise between maximum productivity and the altitude required to stay above most of the weather for flight safety. In addition, certain missions of the multipurpose aircraft require an altitude of about 25,000 ft.

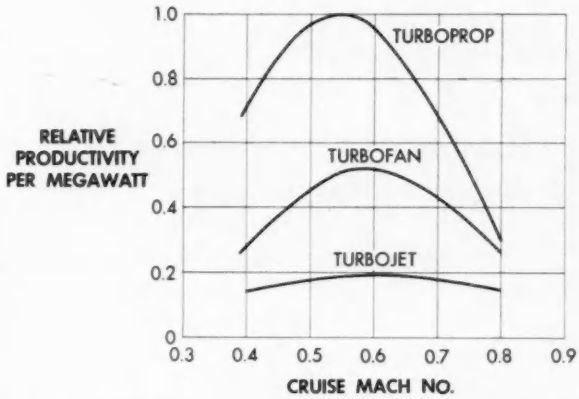


Fig. 1 — Effect of cruise speed on productivity of nuclear aircraft — constant payload.

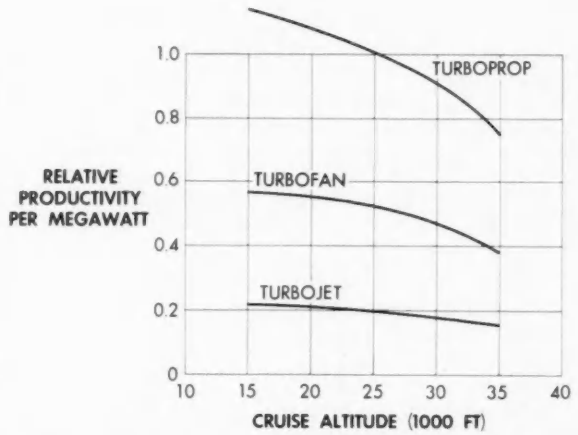


Fig. 2 — Effect of altitude on productivity of nuclear aircraft — constant payload.

To Order Paper No. 167B . . .
from which material for this article was drawn, see p. 6.

Rankine Cycle Selected for SNAP 2

Based on paper by

Guveren M. Anderson

United States Atomic Energy Commission

THE RANKINE CYCLE was selected for the SNAP 2 space power system over the Brayton and Stirling cycles after the limiting factors of (1) maximum reactor coolant outlet temperature, (2) available heat sink area (110 sq ft), and (3) reasonable time allotment for development had been studied.

Comparing the various real cycles with the ideal Carnot cycle shows that the saturated Rankine cycle most closely approaches the ideal cycle efficiency and thus gives the optimum system. This close approach is obtained by the isothermal heating and cooling phases of the saturated Rankine cycle, which allows much better utilization of available temperature ratios than provided by other cycles such as the Stirling and Brayton.

Both the Brayton and Stirling cycles were attractive because the problems of boiling and condensing under zero-gravity conditions would not be present. The Brayton cycle was eliminated on the basis of uncertainties in producing useful shaft work within the specified conditions of temperature and radiator area. Furthermore, a system based on the Brayton cycle with an efficiency comparable to the Rankine cycle would require an excessively high source temperature (assuming optimistic compressor and turbine efficiencies). A further disadvantage of any gas cycle would be the sole dependence on the heat transfer coefficients of gases, which invariably result in larger, heavier, heat exchangers.

The Stirling cycle was considered because of the successful history of the Phillips air engine, which has demonstrated reasonably good brake thermal efficiencies in small sizes. An engine based on this cycle is expected to be somewhat heavier than the Rankine for the same reason as the Brayton cycle, that is, dependence on heat transfer coefficients of gases. Although the problem of a two-phase working fluid would not be present in zero-gravity, the difficulties of lubricating cylinder walls, bearings, and any necessary gearing, as well as the difficulty of scavenging the oil from the crankcase, would present other problems. Entrainment of lubricant in the working fluid, with ensuing deposition on the interior of the thermal transfer surfaces, would probably reduce the efficiency of any heat exchangers.

Resistance of Materials to Mercury Corrosion

SINCE the SNAP reactor uses mercury for the cycle fluid, the problem of mercury corrosion had to be investigated.

Many materials are available that easily contain mercury at the high cycle operating temperatures for long periods of time with no structural deterioration. A mass transfer problem, however, still remains. Mass transfer occurs as a result of contaminant materials dissolving in the liquid mercury and depositing out in lower temperature regions, the boiling sections, or flow restrictions.

Considerable materials evaluation testing has already been conducted. This has included more than 15,000 hr of constant-pressure convection loops in which boiling and condensing have simulated the action in the prototype mercury system. More than 300 glass capsule tests of many materials, surface treatments, and chemical additives have been evaluated for compatibility in boiling and condensing conditions.

The materials evaluation program is still under way. Based on the results to date, stellites, the 400 series, or the low nickel 300 series stainless steels, with suitable surface treatments, are promising for use in mercury systems.

SNAP Experimental Reactor Tested Successfully

THE successful testing of the SNAP experimental reactor, a sodium-to-mercury heat exchanger, and a complete combined rotating unit, was announced on Nov. 18, 1959.

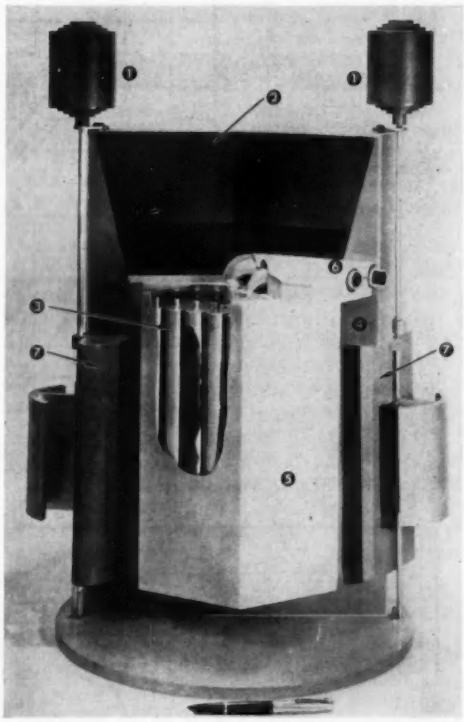
The tests of the reactor, which was designed to power a turboelectric generator for use in space vehicles, were made at an AEC facility of the Atomics International Compact Power Group.

An operational model of this small reactor will eventually provide the heat power necessary to produce several kilowatts of electric power for very long periods of time . . . completely automatically and unattended.

The fueled portion of the reactor core is contained in 61 stainless-steel cylinders 1 in. in diameter. Each cylinder contains a 10-in. long fuel element with a 1½-in. beryllium reflector at each end. This bundle of cylinders fits into a hexagonal can, which measures 8 in. across the flats and 14 in. in length. A reflector of beryllium 2–3 in. thick surrounds the entire core. The active portion of the core (neglecting end plugs) is slightly under ⅓ cu ft. Reactor control is accomplished by means of rotating drums made of reflector material. A model of this assembly plus a conceptual shadow shield for payload protection is shown at the right.

The plan is to combine this reactor core with a prototype turboelectric conversion unit being developed by the New Devices Laboratories of Thompson Ramo Wooldridge, Inc., under a subcontract to Atomics International.

Thus, the next major step is the assembly of the combined rotating unit (turbine, alternator, bearings, and two pumps), boiler, and condenser into a complete power conversion system and the testing of the completed unit using a reactor as the heat source. The present status of the SNAP 2 development indicates that flight-type power systems will be available by 1963.



Full-scale model of SNAP 2 reactor: (1) control motors, (2) shielding, (3) fuel elements, (4) reflector, (5) core vessel, (6) coolant lines, (7) control drums.

Potential missions that can use the SNAP 2 system include: surveillance satellites, communications satellites, space station power systems, lunar station power systems, and solar system probes.

Fig. 1 illustrates that the Stirling cycle at 1250 F would achieve efficiencies comparable with a mercury Rankine cycle at 1000 F if both are held to the same heat sink temperatures. The Rankine cycle radiator is practically isothermal, while both the Stirling and the Brayton cycles have relatively large temperature drops through the radiator, thus reducing radiator effectiveness.

The Rankine cycle takes advantage of the latent heat gained from phase changes, the lower flow rates, and the isothermal heat transfer to attain high efficiencies, light weight, and good reliability within the temperature and radiator area limits. The difficulties associated with phase changes in a zero-*g* environment have been partially solved by utilizing the viscous properties and the velocities of the fluid to achieve phase separation in the designs of the boiler and condenser. Experiments performed by Thompson Ramo Wooldridge indicate that this design approach may be successful. The

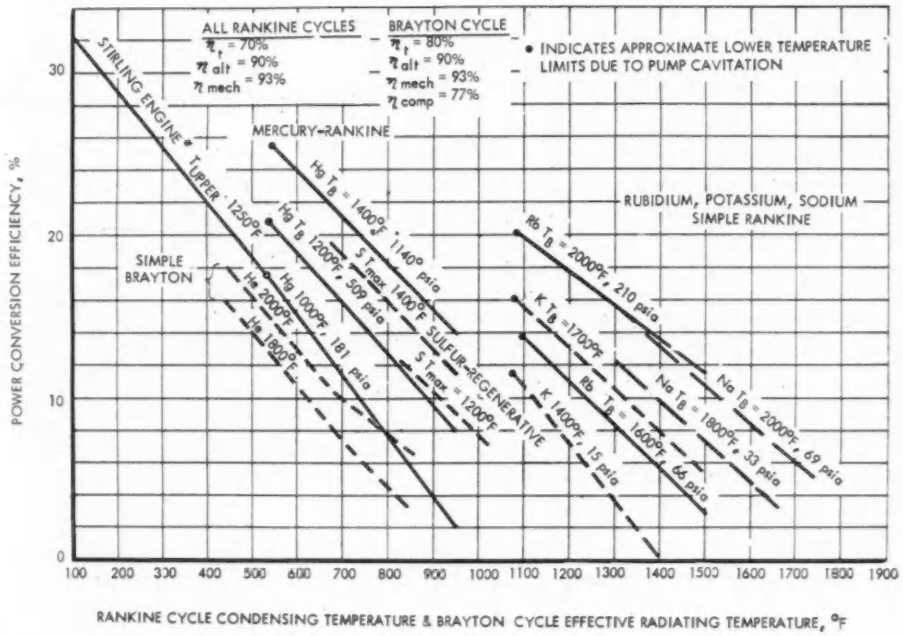

ALL RANKINE CYCLES
η_t = 70%
η alt = 90%
η mech = 93%
BRAYTON CYCLE
η_t = 80%
η alt = 90%
η mech = 93%
η comp = 77%
• INDICATES APPROXIMATE LOWER TEMPERATURE LIMITS DUE TO PUMP CAVITATION
STIRLING ENGINE
T UPPER 1250°F
MERCURY-RANKINE
Hg T_B = 1400°F, 1140° psia
Hg T_B 1200°F, 509 psia
Hg 1000°F, 181 psia
S T_{max} 1400°F
SULFUR-REGENERATIVE
S T_{max} = 1200°F
SIMPLE BRAYTON
He 2000°F
He 1800°F
RUBIDIUM, POTASSIUM, SODIUM SIMPLE RANKINE
Rb T_B = 2000°F, 210 psia
K T_B =1700°F
Na T_B = 2000°F, 69 psia
Na T_B = 1800°F, 33 psia
K 1400°F, 15 psia
Rb T_B = 1600°F, 65 psia
POWER CONVERSION EFFICIENCY, %
RANKINE CYCLE CONDENSING TEMPERATURE & BRAYTON CYCLE EFFECTIVE RADIATING TEMPERATURE, °F

Fig. 1 — Comparison of Rankine, Stirling, and Brayton cycle efficiencies.

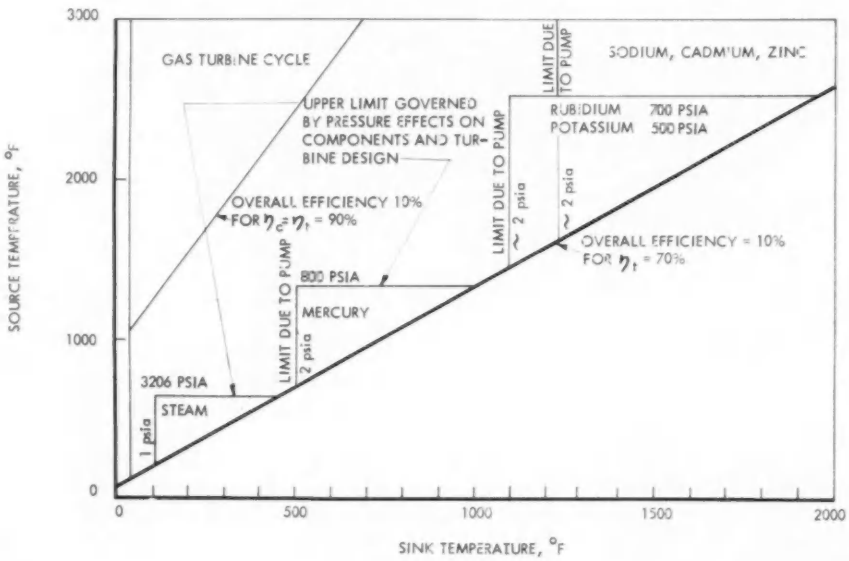


Fig. 2 — Temperature regimes for use of various liquids in Rankine cycle.

Rankine Cycle Selected for SNAP 2

. . . continued

experiments include both laboratory and zero-*g* tests in an aircraft at Wright Air Development Division, Dayton, Ohio, in which test intervals of up to 15 sec at zero gravity were obtained.

The selection of a suitable cycle fluid is based on the pressure and temperature limitations of the fluid, its physical properties, and the availability of containment materials. A simple presentation of the temperature regimes wherein certain Rankine cycle fluids become attractive is shown in Fig. 2. Considering that (1) a reasonable upper pressure for each fluid is limited from the standpoint of containment; (2) a reasonable low-cycle pressure in the radiator is limited from the standpoint of pump cavitation; and (3) a minimum efficiency of 10% overall, then the temperatures of interest for each fluid can be bracketed. It is readily seen that if weight is to be saved by increasing radiator temperature, the alkali metals must be employed as working fluids. Estimated efficiencies for these fluids are also indicated on Fig. 1.

Fluids which can achieve the phase changes desired within the available temperature and pressure limits of SNAP 2 were found to be sulfur, phospho-

rus, and mercury. Phosphorus undergoes several complicated molecular transitions and is difficult to handle. A sulfur cycle was found to be competitive with mercury but required greater heat transfer area. Sulfur, however, was eliminated primarily on the basis of its corrosive properties.

Mercury was selected as the best cycle fluid because it had been in use in several stationary power plants in the United States, and the pressures are reasonable at modestly high temperatures, thereby permitting the use of reasonable containment methods for the vapor. A considerable amount of information has now been developed concerning the heat transfer, corrosion, and other physical properties of mercury, so that components such as boilers, turbines, pumps, bearings, and alternators can be designed and built, using mercury as a cycle working fluid, a coolant, or a lubricant.

Cycle conditions were finally selected on the basis of weight rather than efficiency. No weight penalty is accrued if the reactor is operated at an increased thermal output; however, the boiler and condenser weights can be reduced by proper combination of boiling conditions and moisture content at the turbine discharge.

The use of a once-through counterflow boiler configuration, coupled with a reasonable temperature difference in the primary coolant loop, allows superheating of the cycle fluid. The superheat approaches the reactor outlet temperature and is obtained with a small weight penalty. This improves the cycle efficiency slightly and, more important, reduces the moisture content of the turbine exhaust. A drier turbine exhaust will tend to ease the erosion problem and is expected to lead to a longer lived, more reliable turbine. As a result of these considerations, SNAP 2 will utilize a somewhat superheated Rankine cycle with an effective radiating temperature of about 600 F.

SYSTEM SCHEMATIC

Fig. 3 is a schematic of the SNAP 2 system showing the components and flow of working fluids. NaK has been selected as the reactor coolant in this case to adapt the powerplant for remote start. The primary NaK loop is composed of the pump, reactor, and NaK section of the boiler. The secondary loop contains the components of the Rankine engine, that is, pump, boiler, turbine, and radiative condenser and subcooler. A third loop supplies the bearings.

The primary loop pump delivers 71.5 lb of NaK per min at 1000 F. NaK is discharged from the reactor at 1200 F.

The secondary-loop pump discharges 45 lb of mercury per min at 175 psia. Sixteen pounds per minute are required for the bearings, 10 lb per min are recirculated through the jet pump, and the remaining 18.6 lb per min are discharged into the boiler. The boiler is heated by NaK entering at 1200 F and leaving at 1000 F and is designed for a 60-psi pressure drop, which provides superheated vapor for the turbine at 115 psia and 1150 F. The superheated vapor is expanded from 115 psia to 7 psia, producing work to drive the alternator, mercury pump, and NaK pump.

To Order Paper No. 154B . . . from which material for this article was drawn, see p. 6.

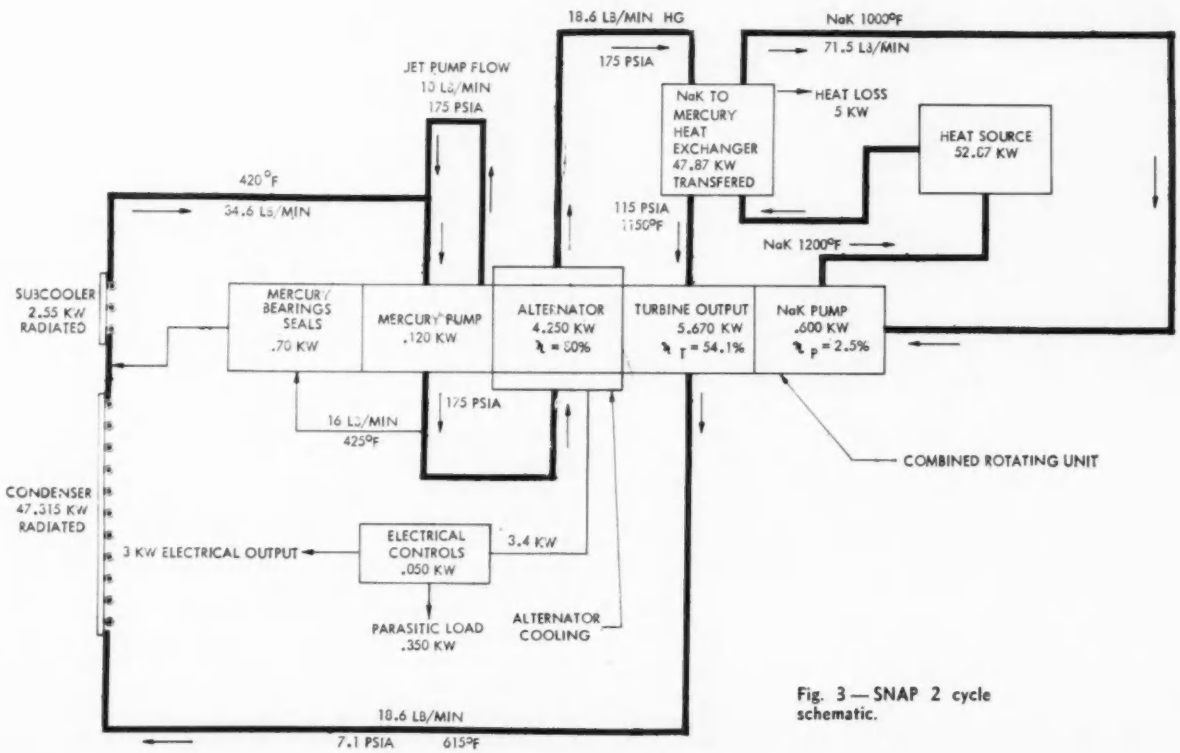


Fig. 3 — SNAP 2 cycle schematic.

Elastomers Increase Acoustic Fatigue Life

. . . when applied to critical areas, tests with Navy A3D aircraft show. Engineers disagree on why it works*

Based on paper by

E. W. Thrall, Jr.
Douglas Aircraft Co., Inc.

ELASTOMER COATINGS have solved the acoustic fatigue problem on the Navy A3D airplane. Specimen tests and ground and flight tests have shown that elastomers are a convenient and effective fix. . . . Stresses were reduced from ½ to ⅓ of their original levels when elastomers were applied at critical locations.

Specimen tests

Approximately one year prior to conducting the flight test program the elevators on the same airplane were found to be in trouble from acoustical fatigue. Because there was no question as to the cause of the damage, an immediate test program was undertaken using specimens which represented many types of structure.

The elevators basically are thin-skinned surfaces with beaded doublers giving the required support for static air loads. The upper skin is 0.016 2024 in. with an 0.025 7075 in. beaded doubler and the lower skin is 0.025 in. with the same doubler. The test specimens were approximately 24 in. square and built in the shape of a triangular box. They were exact duplicates of the airplane structure in so far as the chord dimension and the enclosed volume (Fig. 1).

Specimens were mounted aft of a jet engine and at a position to give the same decibel readings that were received by the elevators when mounted on the airplane during ground run up. The specimens that represented the original structure of the elevators would only withstand one hour of engine time before cracks appeared in the beads. Fig. 2 shows the type of cracks that occurred in the test specimens—they are a duplication of those which were found in flight articles.

Several design configurations for new surfaces were tested with varying degrees of improvement. One configuration which offered the most help in the way of a rework was the one in which a coating was applied to the inner surfaces. Four specimens were sealed so that a silicone solution, Dow Corning A-4000, could be poured into the center of the specimens. The specimens were rotated in a manner to coat all of the interior surfaces, particularly the inclosed area between the internal beaded-doubler and the outer skin. The silicone actually entered this area through holes which had been previously required for venting this otherwise sealed area.

Details of Elastomers Tested

Details of these elastomers are presented not because they are the only ones that will work but because they are the only ones tested. Additional tests will be profitable to determine the most efficient material that can be used based on weight and stress amplitude reducing properties.

DC-A4000, a silicone adhesive which cures at room temperature, has low viscosity and good flowing properties which make it desirable for use as a coating. It is a blend of 75% silicone resins in xylene solvent and is catalyzed by the addition of XY27 catalyst. The catalyzed mixture has a work life of 2½ hr when used as a fill and drain coating. The resulting dry film thickness is 0.003–0.005 in.

PR 611M is a solvent phase dispersion of a high molecular weight polysulfide elastomer in a blend of ketones which forms a coating by solvent evaporation with no catalyst curing required. This particular mixture has a solids content ranging from 35 to 40% and will cure to a dry film thickness of 0.003–0.008 in.

EC-801 sealant is a heavy, liquid, synthetic rubber compound which, upon the addition of EC-807 accelerator, chemically cures to a tough rubber solid. EC-801 is a 100% solids polysulfide polymer.

* See discussion on p. 55.

Fig. 1 — Disassembled sonic test specimen. It is representative of the elevator torque box section.

E. W. THRALL, JR. RECEIVED HIS B.S.M.E. from the University of California. He joined Douglas Aircraft in 1939 and has participated in the load and stress analysis of such airplanes as the A26, TB2D, BT2D, and F3D. He was responsible for all load and stress analysis of the model A3D.

Mr. Thrall, who is Chief, Strength and Dynamics Section, was in charge of the test program described in this paper.

He is an Associate Fellow of the Institute of the Aeronautical Sciences and a Member of the ASME.

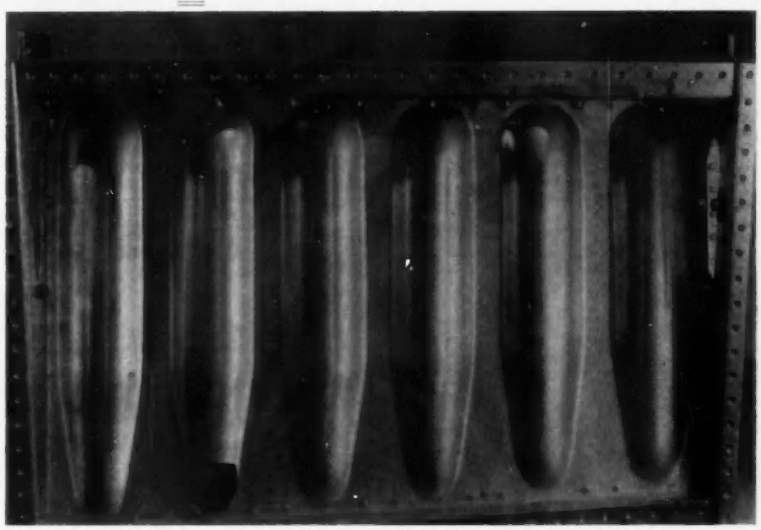


Fig. 2 — Sonic test specimen showing cracks at both ends of beads after 4 hr testing in the ground run-up environment.

The sonic tests of the silicone-sloshed specimens indicated a crack-free service life of 15 hr, and less extensive damage at the end of 25 hr than the original specimen received in one hour's time. It is of interest to note, for comparison purposes, that specimens tested using a solid honeycomb core withstood 100 hr with no damage.

Several months after the original specimen tests were made, another test program was conducted using a Product Research Co. elastomer, PR 611M, and this withstood 75 hr of sonic test with no cracks occurring in the beaded structure.

Flight test program

As a result of the success achieved with addition of elastomers to the elevator structure, it was thought possible that similar beneficial effects could be obtained for other structural items troubled with acoustic fatigue.

So approximately half-way through the flight test program, several areas were modified by the addition of a 3M elastomer, EC-801. These areas were modified as follows:

1. Fin leading edge area was modified by the addi-

Table 1 — Summary of Flight Test Data

The following table presents a compilation of the flight test oscillograph data. The figures given are the trace deflections in inches. All values shown are the max. displacements of the trace. All trace deflections are for the high frequency condition except as noted for the positive high-angle-of-attack (+HAA) condition. This high frequency data is between 200–400 cps.

Note: Modified Structure consists of adding EC-801 (sealant) in vicinity of the strain gages for Channels 5, 10, 15, 35, 40.

		GROUND RUN-UP				LEVEL FLIGHT CONDITIONS								FLIGHT MANEUVERS						
COLUMN		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		Original Struct			Mod Strut	Original Struct			Modified Structure		Original Structure					Modified Structure				
		Min Power	Maximum Power, 95% rpm							Min Power	Max. Power		Req. Power	Landing Approach S.B.Open Gear Dn Flaps Dn Reduced Power	Wave-Off S.B.Open Gear Dn Flaps Dn Max Power	+ H A A		LABS MANEUVER		
		Fin Folded		Fin Spread		480K	500K Speed Brakes Open	500K Speed Brakes Closed	500K	500K 80% rpm	530K	High Mach No.	Cruise at Alti-tude			High Freq.	Low Freq. Approx. 10 cps	Run-In	Pull Up	Max Buffet
Fin Leading Edge Rib	Chan. 10 L.H.Side	.14	.95	1.15	.35	.16	.38	.26	.16	.08	.26	.18	.24	.16	.34	.17	.42	.21	.16	.11
	Chan. 20 R.H.Side	.10	.92	.98	.51	.21	.37	.26	.29	Inst. Failure	.37	.13	.15	.14	.37	.16	1.0g	.20	.19	.08
Fin Torque Box	Chan. 20	.15	.95	.90	.87	.29	.50	.40	.50	.21	.60	.15	.18	.16	.56	.52	.31	No	Records	
Speed Brake	Chan. 15	.14	1.40	1.40	.47	1.10	.22	1.50	.36	.06	1.31	.28	.73	.93	2.43	.16	.14	.28	.34	.11
Lower Rudder	Chan. 30	.16	1.30	1.32	1.50	1.02	1.70	1.42	1.54	1.12	1.79	.10	.08	.16	.54	.14	.72	.75	.84	.36
Dorsal Fin	Chan. 35 Fwd.	.06	.34	.34	.45	1.10	1.03	1.12	1.03	.27	Not Readable	.16	.16	.10	.22	.29	.39	1.49	1.60	.17
	Chan. 40 Aft	.07	.30	.40	.38	.28	.35	.27	.27	.11	.24	.12	.16	.10	.18	.16	.28	.31	.36	.11
Fin Stub	Chan. 45	.07	.42	.44	.44	.79	.60	.66	.62	.62	.85	.10	.16	.06	.20	.16	.18	.89	.75	.09

tion of EC-801. This elastomer was applied in the form of a bead along the rib to skin joint, following all free edges. For test purposes this was done for the rib with the strain gages and each adjoining rib.

2. The speed brake was also modified by the addition of an EC-801 bead running the length of the skin to bulkhead mating surfaces in the area where the strain gage was located.

3. A bead of EC-801 was applied to the one free edge which was accessible between the dorsal skin and its supporting ribs.

Table 1 presents comparative data which shows the reduction in stress resulting from the addition of the elastomer EC-801.

To obtain the necessary information, strain gages were used in each area surveyed (Fig. 3) — oriented at right angles to and centered on the line of crack formation. This information, plus pressure pick-up data, were recorded on an oscillograph. The data in Table 1 are the actual maximum peak-to-peak trace deflections in inches.

Test results

Tests run to date on specimens sloshed with an elastomer do not show any appreciable change in frequency, but show a sizeable (½-⅓ of original level) reduction in stress amplitude.

These elastomers form a low-grade bond between the skin and frame or stiffener, and consequently, lower the stress concentrations at the rivets, screws, or spot welds.

When using such solutions as DC-A4000 and PR 611M, a good penetration of the faying surface is provided and results in a respectable adhesive strength. When panel cracking is the problem, the elastomer must be applied to both sides of the flange which is in contact with the skin. This was evident on the dorsal fin area where it was impossible to apply a bead of EC-801 to both sides of the rib with the result that skin stress amplitudes were not reduced.

DISCUSSION

Disagreement on How Elastomers Improve Fatigue Life

Boeing personnel agreed with the author that the elastomers increased fatigue life by redistributing the stresses in the vicinity of fasteners.

However, there was some disagreement with this explanation for the effectiveness of elastomers.

Dr. P. W. Smith of Bolt Beranek and Newman felt that the main effect of the elastomers is probably an increase in the damping. Reasons are:

1. The relatively small values of elastic moduli for elastomers indicates they would not take much of the load; and

2. It is probable that the strain gage measures a nominal or average value of strain, not the localized concentrations. So redistribution of the load would not lead to lower readings. The critical experiment, that would reveal the correct interpretation, would be the comparison of strains at a central point of the panel (away from the boundaries) with and without the elastomer. With increased damping, the strain there would be reduced; redistribution of the load at the boundary would have but slight effect on the strain at a central point.

Among those who agreed or who had experience indicating that damping was the most probable mechanism were: Mr. Nelson of Republic Aviation, and Messrs. Corten and Fransson of Pratt and Whitney.

Mr. Sheaf of Olmstead Air Force Base indicated that fatigue problems in compressor blade of U. S. Navy jet engines had been cured by applying elastomer coatings. Personnel concerned felt that, in that case, the benefit derived was due to protection against corrosion.

To Order Paper No. 164A . . .
from which material for this article was drawn, see p. 6.

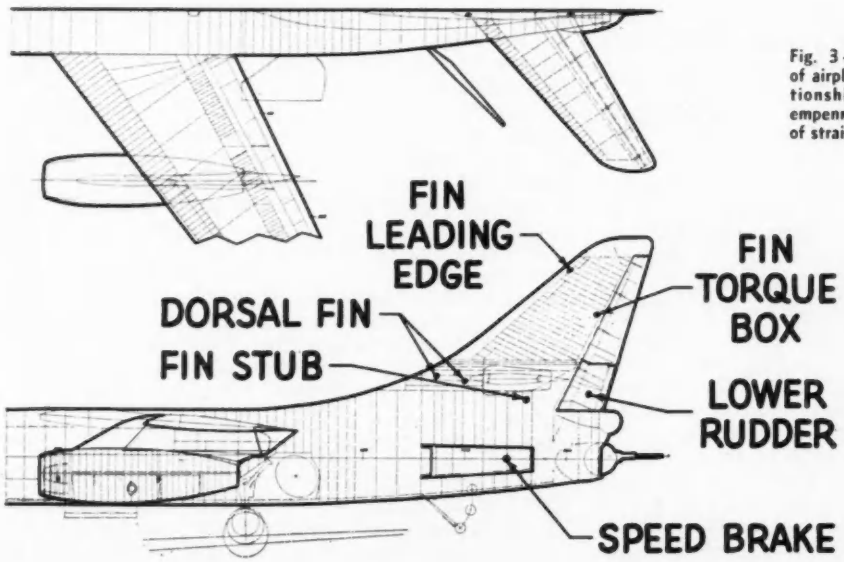


Fig. 3 — General layout of airplane showing relationship of engine to empennage and location of strain gages.

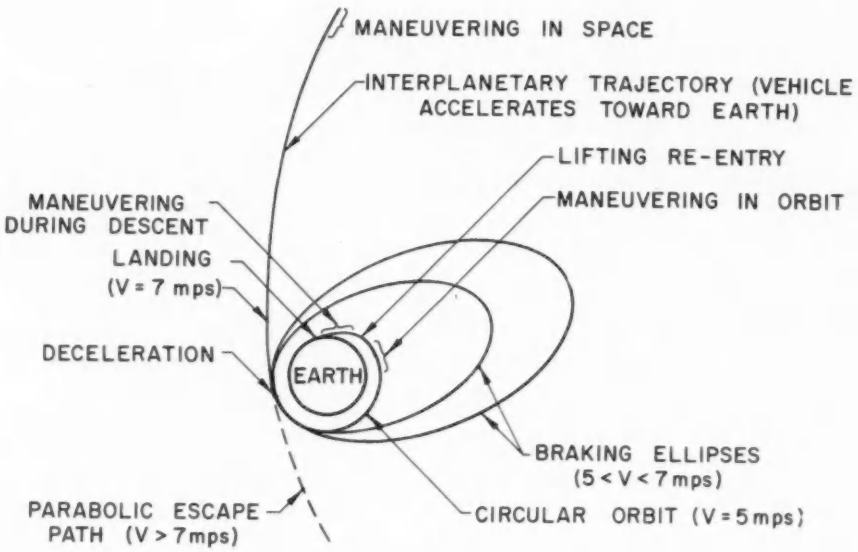


Fig. 1 — **Return-to-earth portion of mission.**

Landing a returning space ship

Reaction devices and aerodynamic control surfaces are can cope with the wide range of changing environmental conditions and

Based on paper by

James W. Clark

Research Laboratories, United Aircraft Corp.

VEHICLES returning from interplanetary missions need two kinds of devices to control attitude and flight path:

- Reaction devices — for use in space and within the earth's atmosphere.
- Aerodynamic control surfaces for use within the earth's atmosphere.

With suitable devices of these types, the vehicles will be able to execute the series of maneuvers needed to land at a predesignated airfield on the earth.

As shown in Fig. 1, the vehicle accelerates as it traverses an interplanetary trajectory toward the vicinity of the earth, decelerates, enters an orbit, and injects itself into the atmosphere on a re-entry path. Control over the landing point is achieved by maneuvering on the interplanetary trajectory at a point far from earth, where its gravitational attraction is small, maneuvering in orbit, and maneuvering during descent into the atmosphere. These maneuvers require control over the orientation of the vehicle with respect to the flight path and stabilization against disturbances caused by the external environment and by the vehicle itself.

The maneuvering and stabilization problems discussed are illustrated with computations for a hypothetical circular-planform vehicle, which would have a lens-shaped cross-section and rounded edge; the aerodynamic properties of a circular flat plate (Fig. 2) were used in the actual calculations. The circular planform vehicle was selected for this analysis because of its favorable aerodynamic heating and deceleration characteristics. From a performance standpoint, the important characteristics of the vehicle are: weight, $W = 4000$ lb; wing loading, $W/S = 15$ psf; diameter, $d = 18.5$ ft; and moment of inertia in pitch, $I_y = 2640$ slug ft^2.

Maneuvering in space

To understand the reasons for maneuvering in space, it is necessary to consider the penalties involved in maneuvering later in the mission when the vehicle is in orbit about the earth or during descent

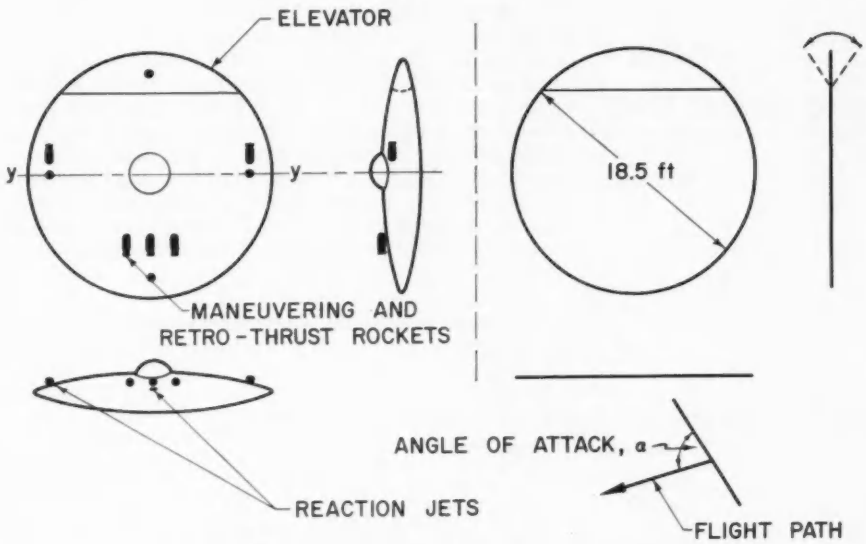


Fig. 2 — **Circular planform vehicle and circular flat plate.**

is a tricky business

both needed to provide controls that

vehicle stability characteristics.

through the atmosphere. By turning during descent and thereby converting kinetic energy into lateral range, the vehicle can reach points approximately 600 nautical miles to either side of the original flight path. This limitation on maximum gliding range places a limitation on the allowable earth orbits from which a successful re-entry and landing at a specific airfield can be made. Changing from an undesirable orbit to one from which the landing point can be reached requires a large amount of energy (a large mass of rocket propellant) so that all but minor orbit corrections are prohibitive. Therefore, the interplanetary trajectory on which the vehicle approaches the earth must terminate in an earth orbit that is very close to the band of allowable orbits from which a landing can be made.

To achieve an acceptable orbit, precise maneuvering during the interplanetary flight is necessary. From the standpoint of the minimum required rocket propellant weight, this maneuvering is most efficiently done at a low initial velocity measured with respect to the earth. The lowest velocities on the trajectory occur early on the return mission, since at these great distances the gravitational attraction of the earth has not accelerated the ve-

THIS ARTICLE . . .

. . . is drawn from Part I of a paper dealing with the problem of providing a control system that is effective throughout a wide range of rapidly changing environmental conditions and that can cope with a wide range of vehicle stability characteristics.

Part I is by James W. Clark, a research engineer in the Research Laboratories of UAC.

Part II of the paper, by J. Harold Ahlberg, head, Mathematical Analysis, describes an inductive experiment performed at the UAC Research Laboratories on an IBM 704 computer to determine the feasibility of using numerical methods to optimize the dynamic response of a physical system in a changing environment.

This study was not specifically framed for a particular physical problem.

The analog computer simulation described in Part I of the paper indicates, however, that application of such numerical methods to the control system of a re-entry vehicle is feasible.

Landing a returning space ship

. . . continued

hicle. Extremely accurate guidance equipment is necessary to determine the amount of maneuvering required.

In contrast to operations within the atmosphere, no aerodynamic forces are developed on the vehicle in space and hence the direction of the flight path cannot be changed merely by changing the attitude of the vehicle. A reaction device thrusting at a suitable angle with respect to the original flight path is necessary for this purpose. The acceleration of the vehicle in the direction of this thrust force results in an added "characteristic velocity" which, when

Table 1 — Summary of Control System Requirements

(Circular Planform Vehicles)

Phase of Flight	Objective	Max Accelerations		Type of Control System	Thrust of Reaction Devices,[a] lb	Dynamic Pressure, psf	Velocity[a]	Max[a] Temperature, R	Source of Disturbances
		Normal	Axial						
Maneuvering in space	Adjust point of entry into earth orbit	Neg	Neg	Reaction plus maneuvering rocket	0.1 1.0[b]	0	Well below 7 mps	—	Control inputs (see also Table 2)
Interplanetary trajectory	Approach vicinity of earth	Neg	Neg	Reaction	0.1	0	7 mps	—	Table 2
Deceleration	Capture by earth's gravitational field; enter earth orbit	0–2g toward earth	½–1g dec	Reaction plus retrorocket; or reaction and aerodynamic plus lift	100 2000 100	0 0–50	7 to 5 mps	— 2000–3000 R	Control inputs, gusts, heating effects
Braking ellipse	Cooling; part of gradual deceleration procedure	Neg	Neg	Reaction	0.1	0	7 to 5 mps	—	Table 2
Circular orbit	Travel to point of initiation of re-entry	Neg	Neg	Reaction	0.1	0	5 mps	—	Table 2
Maneuvering in orbit	Adjust orbit so re-entry path will lead to landing site	0–1g	0–1g dec	Reaction plus maneuvering rocket	100 2000	0	5 mps	—	Control inputs (see also Table 2)
Lifting re-entry	Enter atmosphere, decrease velocity using lift modulation	5g away from earth	1g dec	Reaction and aerodynamic plus lift	100	0–60	5 mps to 15,000 fps	2000 R	Control inputs, gusts, heating effects
Maneuvering during descent	Final adjustment of flight path; glide to landing point	1g	½–1g dec	Aerodynamic	—	50	15,000 fps to 137 fps	2000 R	Control inputs, gusts, heating effects
Landing	Soft, conventional landing ($C_{L_{max}} = 0.65$)	—	—	Aerodynamic	—	22.5	137 fps	—	Control inputs, gusts

[a] Order of magnitude numbers.

[b] Depends upon accuracy of guidance during escape from the planet.

added vectorially to the initial velocity, results in a new velocity and a new flight path direction (Fig. 3).

Table 1 summarizes the maneuvering and control requirements for the circular-planform vehicle maneuvering in space. The vehicle will require a three-axis reaction attitude control system consisting of individual reaction units, each developing on the order of 0.1 lb thrust, and a reaction maneuvering rocket of about 1.0 lb thrust. Changes in the flight path direction will be made gradually over a long interval of time. The possible sources of attitude perturbation torques are listed in Table 2. Possible low-thrust reaction devices for use in this flight regime include small chemical rockets, steam rockets, and electrical propulsion units (ion and plasma engines). The choice of these devices will be based primarily on the duration of the flight, the total impulse required for maneuvering and stabilization, the weight of the associated equipment (especially power-generating equipment for the electrical units), system reliability, and their availability.

Table 2 — Sources of Attitude Perturbation Moments

1. Thrust-axis offset and misalignment.
2. Drag of solar atmosphere ("ether fatigue" or "space gusts").
3. Motion of the crew and moving parts of the vehicle.
4. Gravitational fields of celestial bodies.
5. Magnetic and electric fields of the earth.
6. Meteoroid and cosmic ray bombardment.
7. Radiation pressure of the sun.

Stabilization for interplanetary trajectory phase of flight

Except during the relatively brief period of maneuvering mentioned in the preceding section, the control system is used only for attitude stabilization during the interplanetary trajectory phase of the flight. The disturbing moments which the control system must counteract are those listed in Table 2. The control system, which is designed primarily for the maneuvering portions of the trajectory, should be capable of overcoming the increase in the magnitude of these disturbances as the vehicle approaches the earth.

Deceleration near earth

As the vehicle approaches the vicinity of the earth on the interplanetary trajectory, its velocity increases to more than 7 mps, which is the escape velocity from the earth. The next control objective is to maneuver in a way that will cause the vehicle to be captured by the gravitational field of the earth, and eventually to enter into a circular orbit (at a velocity of about 5 mps) from which a re-entry and landing at the predesignated airfield can be made.

Two methods can be used to produce the characteristic velocity decrement of 2 mps. In the first, retro-thrust is applied to the vehicle as it passes the earth, causing it to decelerate (Fig. 1). When the velocity decrement is equal to the required 2 mps, the vehicle will enter a circular orbit at approximately the altitude of application of retro-thrust.

When the initial velocity decrement is less than 2 mps, the vehicle will enter a large elliptical orbit around the earth (a braking ellipse) having a perigee at the point of application of retro-thrust. In the latter case, additional retro-thrust must be applied at the perigee in order to further decrease the velocity to that for a circular orbit. The initial firing of the retro-rocket must, however, decrease the velocity below 7 mps to prevent the vehicle from escaping from the earth's gravitational field.

The second method of providing a characteristic velocity of 2 mps involves the use of aerodynamic forces instead of retro-thrust. As shown in Fig. 4, the vehicle approaches the earth inverted, traveling along a trajectory which cuts deep into the atmosphere. As the dynamic pressure increases, the angle of attack is increased and a lift force is de-

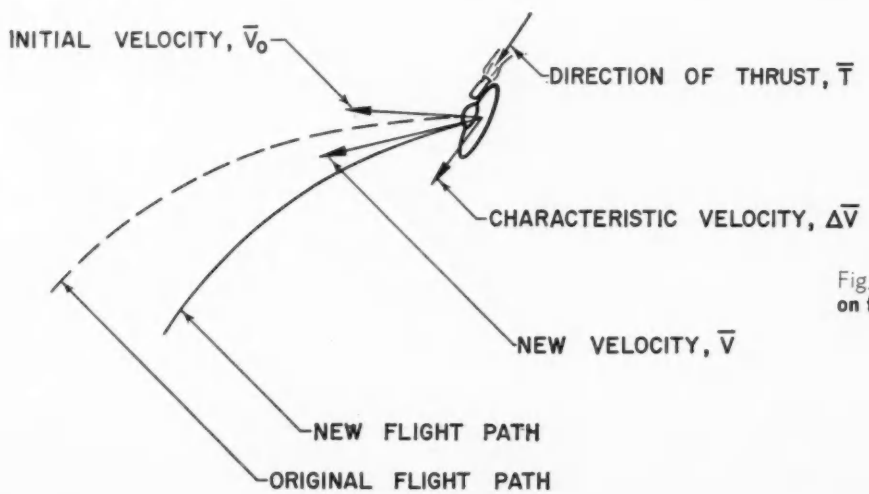


Fig. 3 — **Effect of thrust on flight path.**

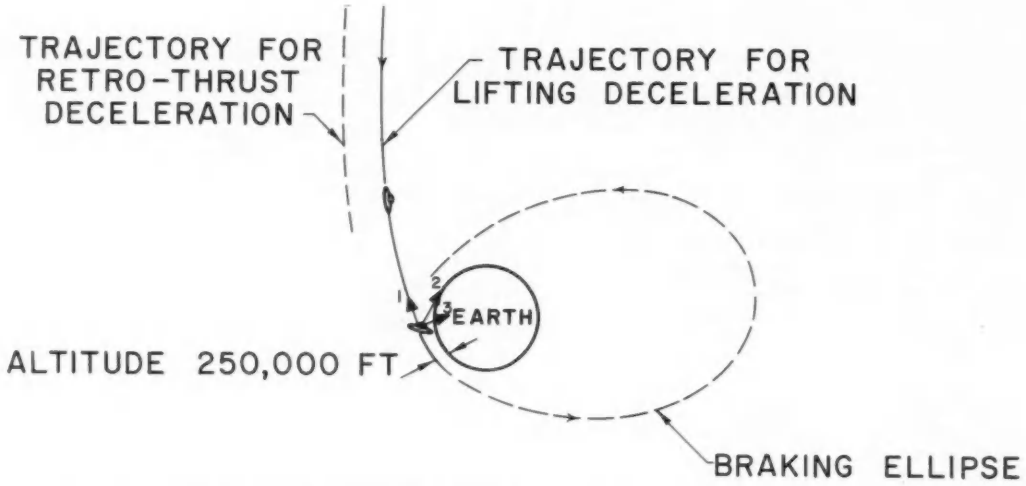


Fig. 4 — **Use of aerodynamic force for deceleration.** (1) component that decelerates vehicle; (2) aerodynamic force; (3) component that curves flight path.

Landing a returning space ship

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veloped. This force serves two purposes: its component along the flight path decelerates the vehicle (in the same manner that retro-thrust does), and its component normal to the flight path causes the vehicle to curve around the surface of the earth and therefore to prolong its contact with the atmosphere (Fig. 4).

To achieve a velocity decrement of 2 mps, the maximum aerodynamic force required is about twice the weight of the vehicle (a g-loading of 2.0). Even at these high velocities, it is necessary for the vehicle to penetrate the atmosphere to an altitude of 250,000 ft above the surface before the dynamic pressure is sufficient to develop the required aerodynamic force. During the maneuver, the pilot is on the protected side of the vehicle in a separated flow region in which the heat transfer is a small fraction of that at the stagnation point. If the entire velocity decrement were attempted on the first pass, the temperature of the structure would become excessively high; therefore it is necessary to use multiple-pass braking, with intermediate braking ellipses, during which time some of the heat input can be radiated from the vehicle. Using this technique, the maximum stagnation temperature can be held to 2000–3000 R.

The major control problems associated with the use of lift force for deceleration result from the necessity of maneuvering in a rapidly changing environment.

The control system for vehicles operating in this environment will consist of reaction devices of thrust levels on the order of 100 lb and aerodynamic control surfaces similar to the elevator shown on the vehicle in Fig. 2. The reaction devices must be used at dynamic pressures below approximately 15 psf; at higher dynamic pressures, the elevator may be used to supply the required trimming moment. The vehicle itself will be designed to have positive aerodynamic static stability (the center of gravity will be forward of the center of lift) at hypersonic speeds. The primary disturbing moments during this phase of operations will result from control inputs by the pilot, atmospheric gusts, wind shear layers, and small changes in the airframe shape due to aerodynamic heating.

Maneuvering in orbit

The deceleration procedure described in the foregoing section results in a circular orbit around the earth (preceded in the case of multiple-pass braking by intermediate braking ellipses). The objective of maneuvering in both circular and elliptical orbits is to make the small position, altitude, and heating changes necessary to reach the landing point on the surface of the earth.

Fuel requirements for changes in orbits preclude large changes except when the change can be made over a long period of time (on the order of days), by means of very-low-thrust reaction devices having thrust-to-weight ratios of about 10^{-4}. For the flight of manned space vehicles, time is a consideration. Therefore, maneuvering will be limited to small orbital corrections, and large reaction devices having thrust-to-weight ratios of 0.5 will be required.

The nomenclature commonly used in discussing satellite orbits is shown in Fig. 5. The variables that can be controlled when attempting to land at a specific point on the earth are the perigee altitude, the position angle of the vehicle in the orbit at a specific time, W, and the inclination angle of the orbit, i.

When the mass ratio is 2.0, that is, when the vehicle is designed such that 50% of its initial mass is rocket propellant, the maximum change in orbit inclination angle which may be attained is only 20

deg. In view of the possibility that orbit position angle and perigee altitude must also be changed, it would be unrealistic to plan for the availability of a mass ratio of 2.0 for changing inclination. Since changes in position and perigee altitude also require large mass ratios, it can be concluded that only small corrections can be made to satellite orbits due to practical limitations on the mass of propellant which the vehicle can carry. It is for this reason that maneuvering in space to achieve an accurate earth orbit is necessary; the characteristic velocity required for a given maneuver (and therefore the mass of propellant required) is minimized when the velocity at which the maneuver is initiated is as small as possible.

Attitude control during maneuvering in an orbit is accomplished by means of reaction devices having thrust levels on the order of 100 lb. The primary use of the control system will be to orient the thrust vector properly with respect to the flight path and to stabilize the vehicle against disturbing torques created by thrust line offset and misalignment.

For attitude control during nonmaneuvering portions of the orbits, low thrust devices (on the order of 0.1 lb thrust) will be adequate. A considerable amount of work is currently being done to determine the sources of the disturbances which perturb the attitude of satellites. Several sources are listed in Table 2.

Lifting re-entry and maneuvering during descent

The use of aerodynamic lift during re-entry into the atmosphere is being widely studied in connection with long-range boost-glide vehicles and successors to the Mercury Man-in-Space ballistic capsule. Its primary purpose is to control the peak aerodynamic heating and deceleration of the vehicle. However, there are also highly desirable additional advantages:

1. Steeper re-entry paths, and hence shorter flight times for penetration of the atmosphere, resulting in lower total heat inputs to the vehicle.
2. Greater tolerance on the allowable re-entry path angle.
3. Some degree of control over the trajectory.
4. Possibility of a conventional aircraft-type landing.

During a purely ballistic re-entry, the trajectory and the major in-flight variables (heating and accelerations) are determined by the weight and drag characteristics of the vehicle (W/C_DS), and by the velocity and angle at which the vehicle initially enters the atmosphere. If the vehicle is designed to

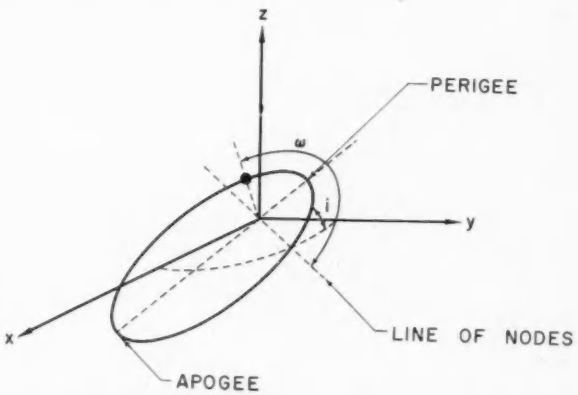

Fig. 5 — **Nomenclature for satellite orbit.** i = inclination angle; ω = position angle.

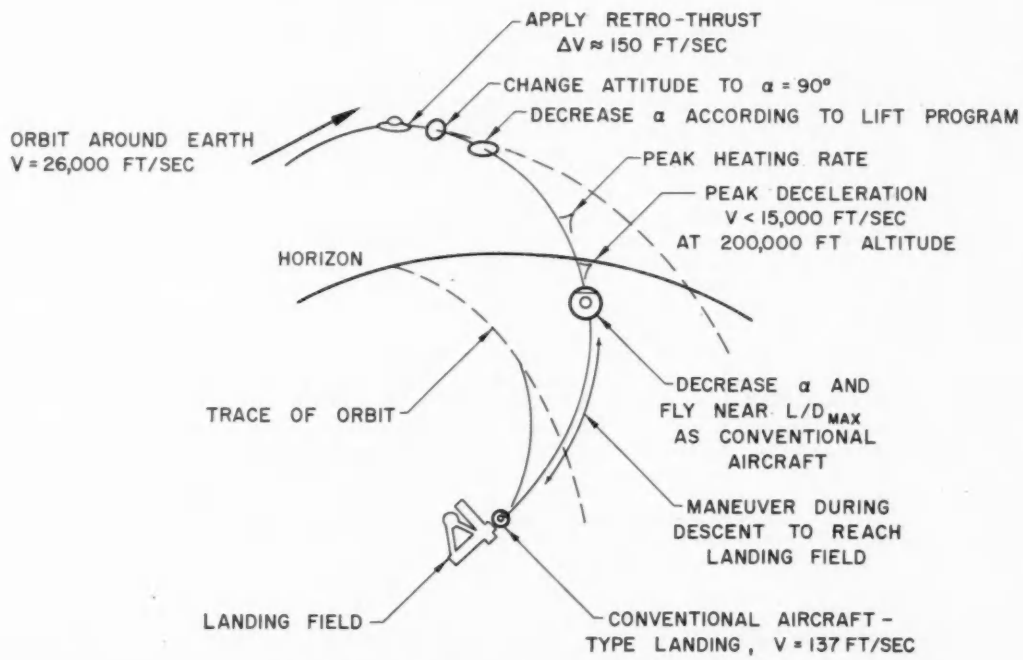

Fig. 6 — **High-drag, low-lift re-entry trajectory.**

Landing a returning space ship

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trim at an angle of attack at which the lift-to-drag ratio L/D is not zero, the aerodynamic lift force generated as the dynamic pressure increases will cause the trajectory to curve. The re-entry dive from a low orbit (100 nautical miles altitude) is initiated by firing a retro-rocket, which decreases the velocity of the vehicle by about 150 fps; the initial part of the trajectory is ballistic since the low air densities do not allow any appreciable lift to be developed. As lower altitudes are reached, the dynamic pressure increases, and lift and drag forces are created. The drag causes the vehicle to decelerate, and the lift causes the trajectory to curve. When the lift-to-drag ratio is high enough, the vehicle will climb out of the atmosphere and dive again, executing a skip re-entry.

A more useful method is the high-drag, variable-lift trajectory control. After retro-thrust the vehicle is rotated to an angle of attack of 90 deg. The angle of attack is then decreased as necessary to follow one of several lift programs; if, for example, the angle of attack is varied so as to maintain constant rate of descent, the trajectory shown in Fig. 6 results. Other successful programs include varying the angle of attack as a function of deceleration and rate of change of deceleration, and also as a function of range-to-go (to a landing field) and rate of change of range-to-go.

During the portion of the re-entry between the time the vehicle is at 350,000 ft until just after the peak deceleration is reached, aerodynamic lift force is used to moderate the heating and deceleration conditions. After peak deceleration has occurred, the lift can be used to convert some of the remaining kinetic energy of the vehicle into range along the original flight path and range in the direction normal to the original flight path. In this manner, errors in the re-entry flight path can be corrected and the vehicle can be maneuvered during the descent to reach the landing field.

As indicated in Fig. 6, the angle of attack of the vehicle must be decreased in order to glide at a high lift-to-drag ratio to achieve maximum range. Starting at this point, for the remainder of the flight, the vehicle can be flown in a manner similar to conventional aircraft, with turns accomplished by banking (rolling).

The capability of the vehicle to maneuver during the descent to reach points off the initial flight path is highly desirable since it allows more tolerance in establishing the orbit from which the re-entry is made. Greater tolerance on the plane of the orbit will reduce maneuvering in space and maneuvering in orbit, with a resultant reduction in the mass of propellant required to be carried and somewhat of a reduction in the required accuracy of the guidance equipment.

In an effort to increase this maneuvering capability of re-entry vehicles, several organizations are studying the possibility of variable-geometry configurations. NASA has suggested the use of folding wing extensions, which would increase $(L/D)_{max}$, decrease the wing loading (resulting in slower landings), and provide better slow-speed stability and control characteristics. Other "glide stretching" techniques, such as the use of small rockets, are conceivable.

With reference to the stability and control aspects of the re-entry and maneuvering descent, it is evident that both reaction devices and aerodynamic control surfaces will be required and that a stability augmentation system capable of operating over a wide range of dynamic pressures and vehicle dynamic characteristics will be necessary. Control about all three axes during retro-rocket firing and during the early stages of re-entry (dynamic pressures less than about 15 psf) must be accomplished by the use of reaction devices. The reaction devices must have thrust levels on the order of 100 lb to counteract the moments produced by retro-thrust offset and misalignment. As the dynamic pressure increases, the stabilization and control moments can be supplied by the aerodynamic control surfaces. Since the dynamic pressure will remain at a

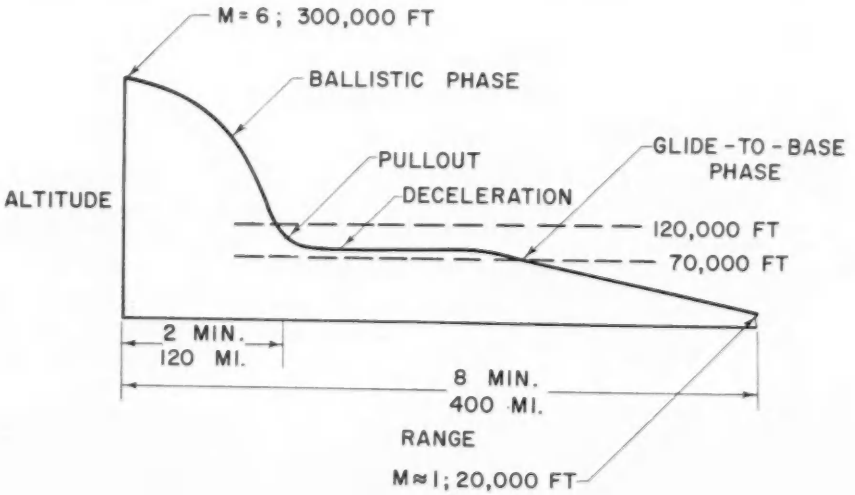

Fig. 7 — **Simulated re-entry trajectory.**

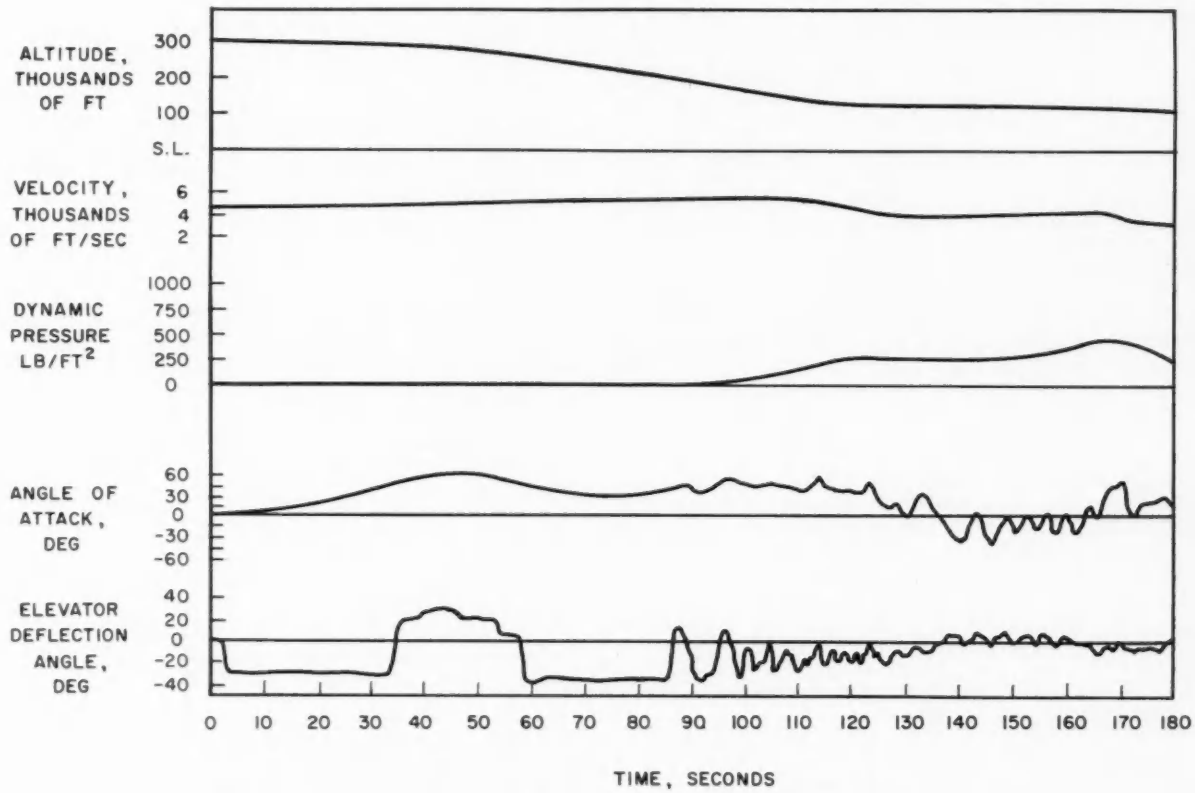

Fig. 8 — **Trajectory data for simulated re-entry without stability augmentation.**

value approximately equal to that experienced at the point of peak deceleration, it will be possible to use the aerodynamic controls for the remainder of the flight. Unfortunately, the lift contribution required from the aerodynamic control surface in order to trim the vehicle at a pitch attitude adversely affects the maximum lift-to-drag ratio when conventional trailing-edge elevators of the type shown in Fig. 2 are used. In order to avoid large decreases in $(L/D)_{max}$, alternate control configurations are under investigation.

The aerodynamic control system will be used for stabilization, for lift programming near peak deceleration, for rotating the vehicle to the angle of attack for $(L/D)_{max}$, and for trimming the vehicle during the maneuvering descent. This must be accomplished under rapidly changing environmental conditions; for example, changing dynamic pressure and Mach number cause changes in the pitching moment available from the surfaces for a given stick deflection, and cause large variations in the natural frequency of oscillation and the damping ratio of the airframe. If variable-geometry features are incorporated in the design, the aerodynamic control system will also have the task of controlling attitude during the configuration transition stage. Very large changes in the stability characteristics of the vehicle will occur in a short time during this stage as the position of the center of lift is changed with respect to the center of gravity.

The primary sources of moments tending to disturb the attitude of the vehicle during the re-entry and maneuvering descent phase of the mission are gusts, wind shear layers, and pilot control inputs. The importance of the latter source of disturbances was observed in a recent series of analog computer simulations conducted at the UAC Research Laboratories. The stability and control problems of a re-entry vehicle of the short-range, boost-glide type (similar in mission to that of the X-15 research airplane) were studied. Some of the results will be shown here to illustrate the type of stability characteristics a re-entry vehicle can have in a rapidly changing environment.

A schematic of the simulated re-entry trajectory is shown in Fig. 7. In this series of simulations only the forces and moments acting on the vehicle in the vertical (pitch) plane were considered. The airframe was of the fixed-geometry, lifting type similar to the X-15 research airplane; continuous attitude control was obtained from pilot-operated elevators and reaction jets (thrust of 100 lb). In representing the aerodynamics of the airframe the true nonlinear variations of the aerodynamic coefficients were retained.

Trajectory data for a typical simulated re-entry flight are shown in Fig. 8. During this flight, no pitch damping augmentation was used, only the aerodynamic control surfaces (the elevators) being employed. The ratio of elevator deflection angle to stick deflection was held constant.

The effect of environmental changes on the effec-

Landing a returning space ship

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tiveness of the control system is evident in Fig. 8. At the very low dynamic pressures encountered early in the flight ($t = 0$–90 sec), the angle of attack response to maximum elevator inputs was too slow, while at the higher dynamic pressures ($t = 120$–180 sec) the response was excessively fast. In addition to the influence of dynamic pressure, the control effectiveness was influenced by Mach number and the combined angle of attack and elevator deflection angle.

Another major effect of the changing environment is the very noticeable change in the period of oscillation of angle of attack and in the damping ratio. During the simulated flight shown in Fig. 8, the combination of short period of oscillation and low damping ratio resulted in a completely uncontrollable configuration in the critical pullout and deceleration phase of the flight. The periods of oscillation and damping ratios encountered during this phase of the flight (without a stability augmentation system) fall into the "unacceptable" and "unsatisfactory-unacceptable for normal operation" categories of pilot opinion.

This discussion has considered the effects of the environment on the pitching characteristics of reentry vehicles; however, it is necessary to provide adequate stabilization and control about all three axes. The control system must be capable of overcoming adverse control moments.

Landing

The vehicle shown in Fig. 2 is capable of executing a conventional landing at 80 knots. This low speed is attributable to the low wing loading ($W/S = 15$ psf); a lift coefficient of $C_L = 0.65$, which corresponds to an angle of attack of approximately 15 deg, was used to calculate the landing speed.

Control during the landing will be accomplished using aerodynamic control surfaces. Sufficient control power must be available to counteract gusts during the approach and to trim at the angle of attack for flare-out. If a variable-geometry configuration is used, the controls must be capable of maintaining stability and changing attitude during transition. For these purposes, it is probable that control surface areas in excess of that needed for the other phases of flight will be necessary.

In addition, it is likely that the forward travel of the center of pressure as the vehicle decelerates through the transonic range to subsonic speeds will require the addition of a fixed aerodynamic surface near the trailing edge in order to maintain adequate static stability in pitch and yaw. A folding wing extension, which is protected during the re-entry and is then unfolded at the start of the maneuvering descent, is one method of providing the necessary area.

To Order Paper No. 175B . . .
from which material for this article was drawn, see p. 6.

New Stops

Based on paper by

A. Bayne Neild, Jr.
U. S. Naval Engineering Experiment Station

CAVITATION-EROSION in the water seal area of a diesel aluminum crankcase has been eliminated by the use of a wide-band cylinder liner water seal designed by the U. S. Naval Engineering Experiment Station. Fabric inserts and tough materials, developed by the Mare Island Naval Shipyard Rubber

Table 1 — Physical Properties of Nitrile Rubber Stock Used in Wide-Band Seals

Initial Physical Properties	
Tensile Strength, psi	4260
Ultimate Elongation, %	420
Modulus at 200% Elongation, psi	1030
Graves Tear at 74 F, lb per in.	236
Graves Tear at 150 F, lb per in.	162
Hardness, Shore A-2, 3 sec	74
Specific Gravity	1.20
Physical Properties after 166 Hr in Boiling 1% Dromus B/Distilled Water Emulsion	
Tensile Strength, psi	3280
Retention of Initial Points, %	77
Ultimate Elongation, %	300
Retention of Initial Points, %	71
Modulus at 200% Elongation[a], psi	1660
Retention of Initial Points, %	161
Graves Tear at 150 F[b], lb per in.	107
Retention of Initials Points, %	66
Hardness, Shore A-2, 3 sec	65
Change from Initial Points	−9
Volume Change, %	9

[a] Based on swollen cross-section.
[b] Based on swollen thickness.

Diesel Cylinder Water Seal

Crankcase Cavitation-Erosion

Laboratory, give the seal adequate strength to withstand at least 3000-hr engine operational periods.

The major objectives of the design were to:

1. Prevent water contact in the vulnerable water seal area.
2. Absorb the damaging effects of cavitation bubble collapse in the machined taper section.
3. Dampen liner vibration by further restricting the free-end movement.

Details of design

The positioning of the seal is shown in Fig. 1. Some material was removed from the steel cylinder liner just above the top O-ring groove to provide clearance for a seal with sufficient cross-section. The seal extends partially across the machined taper section of the crankcase. In this taper section the seal was unable to follow the vibrating cylinder during engine operation and cavitation bubbles formed on the liner were absorbed or dissipated by the resilient seal before reaching the vulnerable aluminum.

Seals were made of several different Paracril BLT compounds. A nitrile rubber was selected because of the need to resist heat, oil, and water. The choice of Paracril BLT was based upon a study of 18 nitrile rubbers in their resistance to distilled water and distilled water containing 1% soluble oil inhibitor.

Results of tests

When the new seals were subjected to a 1500-hr engine laboratory test at loads and speeds to give the wost condition of liner vibration, there was no cavitation-erosion but there was some tearing and deterioration of the seal bands. Fleet tests were then made with 6-cyl service generator engines on 10 ships, and again there was no cavitation-erosion, but there was more tearing and deterioration.

At this point, tougher materials were developed and the toughest of all were reinforced with two types of fabric — 20-denier nylon tricot and nylon tire cord. The seals were then given a 3000-hr cyclic test with considerable overload operation in a 12-cyl engine. All seals prevented cavitation-erosion and the seal reinforced with nylon tricot proved the strongest and showed no apparent deterioration. The physical properties of the toughest material used in the seals are shown in Table 1.

To Order Paper No. 191A . . .
from which material for this article was drawn, see p. 6.

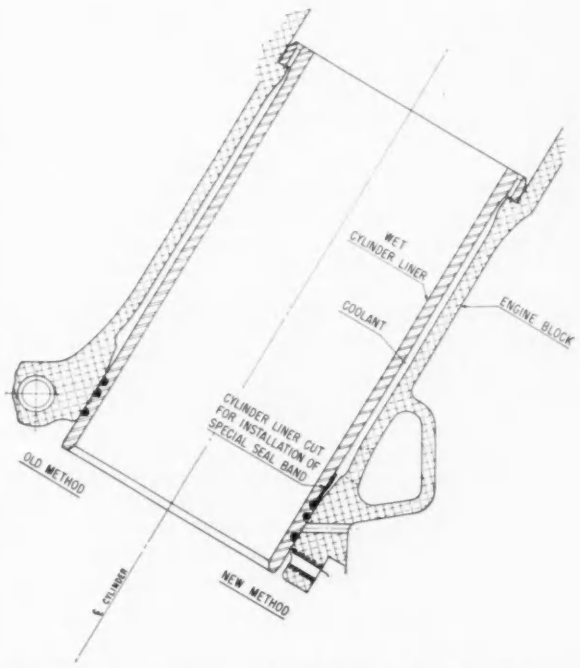

Fig. 1 — Wide-band cylinder liner water seal contrasted with conventional method of sealing. New reinforced nitrile rubber seal has capacity to prevent cavitation-erosion for at least 3000 hr.

Gas Turbine Design

Balanced-Life Gears Give

Computers perform detailed design

Based on paper by

G. J. Huebner

Chrysler Corp.

DESIGNING GEARS to meet the balanced-life concept (where gear and pinion fail simultaneously and maximum capacity is provided in the smallest space) requires careful analysis of why gears fail and consideration in design of gear ratio, pressure angle, contact ratio, scoring factor, bending stress, and compressive stress.

Computers are being used to analyze, extend, and refine gear design concepts. This article discusses their use in the design of gas turbine gearing using the balanced-life approach.

THIS ARTICLE describes the balanced-life concept of gear design — in which the gear and pinion are designed to fail simultaneously. This concept allows a combination of minimum size and maximum capacity in gas turbine application. Various reasons for failure and factors in long gear life are discussed.

The author analyzes the calculations needed and their programming for a digital computer.

Calculating gear designs for production is a time consuming, demanding task to do manually. The use of the computer has changed this — and brought about better gear design by making it possible to study more detailed analyses to evolve optimum solutions.

This article is based on the Sixth L. Ray Buckendale Lecture.

Gas turbine gears present a challenge to the gear designer because of the extremes in speed experienced within the engine. The ability to produce a gas turbine reduction gear with a ratio of 9 or 10 to 1 in a single step (Fig. 1), to have it work right the first time, continue to work quietly and efficiently with extended life, is a technical achievement. In addition, during initial phases of a new engine size determination, the need of quickly providing the powerplant designer with a series of gear sets, any of which may be chosen and each of which will be equally good, approaches the ideal in engineering design work.

High-speed turbine gears differ in design and development complexity from those found in other type engines. Generally, they must be more accurately processed, they must have greater accuracy in their mounting, and the mounts must have greater rigidity than those needed for lower speed gear trains. Failure to start with these fundamentals is a shortcut to trouble, and when high-speed gears fail, the result is often catastrophic (Fig. 2).

Two characteristics of the balanced life concept of gear design are:

1. Adjustment of the thickness of the pinion and gear teeth to compensate for the variation in life between the gear and the pinion. 2. Adjustment of the outside diameters to give equal scoring factors.

2. Adjustment of the outside diameters to give equal scoring factors.

It is desirable that the number of cycles to produce fatigue failure be in proportion to the gear ratio, so that both gear and pinion fail simultaneously. There is little justification for having a gear destroyed by a pinion which has failed. So, the pinion is strengthened at the expense of the gear. This provides a gear set with longer life at no added penalty in size or cost. It also gives more gear capacity in a smaller space.

In the gas turbine, a gear mounted on the high-speed output shaft may go through as many as 10 million cycles in about 3 hr. Thus, fatigue damage

Capacity-to-Size Optimum

analyses to provide best gear for the job.

is a definite threat. Gas turbine design today is at the stage where frequent changes in the speed and torque characteristics are made in order to evolve the best powerplant configuration. Where large speed reductions are needed, gear design is a major factor in the layout of the powerplant. The designer can't wait for traditional methods of gear design to give a complete answer before major engine dimensions are set down. Balanced-life design charts permit the selection of gear dimensions quickly, even though the ultimate refinement of the gear design must be finally accomplished by more detailed methods. Working with preliminary data given by the charts, final dimensions can be fixed by the conventional gear design process or by computer analysis of the problem. Then it is necessary to make only minor adjustments in engine layout to accommodate the final gear design.

Balanced-life gears are used in gas turbines to combine minimum size with maximum capacity. To get comparable capacity, common gear design practice would call for larger pinions which would have limited life. This could lead to several stages of reduction gearing to keep the gear train within the envelope of the vehicle outline.

Balanced-life design concepts aren't a solution to all gear problems. If standard gears are available, and they are of sufficient size and capacity to do the job, it is unnecessary and unwise to spend extra engineering time and effort to develop a balanced-life design for experimental application. Frequently analysis shows that a standard pinion will outlive other components, and will define a gearset of reasonable size that is capable of carrying the load. Thus, it would be unnecessary to use even the most short-cut phases of the balanced-life concept. Further, if size, load capacity, and life are not critical, it is desirable to economize by using available standard tools. With balanced-life gears there is a variation in tooth proportions between the gear and pinion, so no two designs are likely to require the same tooling. Also, a different cutter must be used for each piece in the gear set. And, balanced-life gears often have pressure angles that aren't

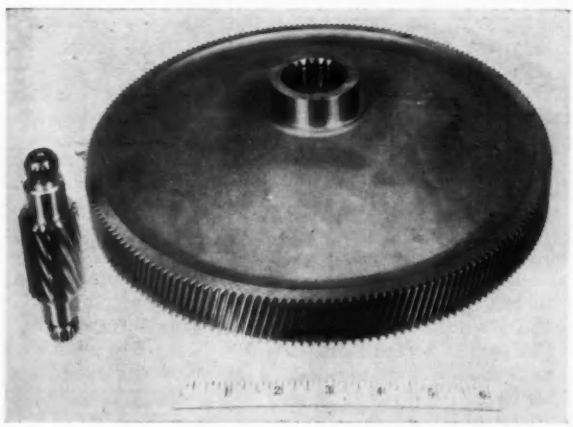

Fig. 1 — Main reduction gear for automotive gas turbine.

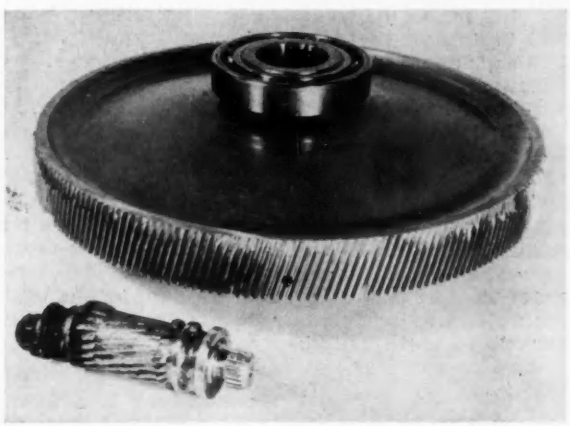

Fig. 2 — Typical failure of gearset operating at high speeds.

Balanced-Life Gears

. . . continued

commonly available in standard cutters, which also precludes the use of standard tools.

Bear in mind that these must be practical gears which are used for varying loads and speeds, and certain assumptions are necessary to take these factors into account. Fig. 3 shows a gas turbine accessory drive set which operates under widely varying conditions of torque and speed.

Why gears fail

An analysis of why gears fail and how these failures affect the balanced-life design concept must include consideration of the following:

1. Wear.
2. Bending.
3. Scoring.
4. Pitting.
5. Shock.

Wear

Some gears wear out. Fortunately, however, high-speed gears are not usually faced with this problem since ample lubrication must be provided to carry away the heat generated by high sliding velocities.

Bending

Repeated bending of gear teeth can result in fatigue failure. While loads may fall within the elastic limit, repeated application may cause a crack to form at the surface. This reduces the effective area of the tooth and causes further propagation of the crack. And, if a fatigue crack is found in one tooth, cracks will usually be found in others. Bending stresses can be proportioned through the use of the balanced-life concept.

Scoring

Some gears fail by scoring. That is, the gears wear out before they wear in. Scoring shows up as an abrasive-type wear taking place near the tip or the root of the tooth, and is due to minute welds that take place at points of minor surface roughness which penetrate through the oil film. In high-precision gears of hardened steel there is usually little wear-in problem. Those that do fail by scoring usually do so upon initial application of the critical load and speed.

Design analysis can reveal if the gears will score; the maximum scoring factor occurs when the product of speed and square root of torque reaches its maximum value. If the analysis gives a no-score answer, a scoring balance isn't needed. The tendency to score is calculated by considering the heat generated in sliding from either the beginning or the end of tooth action.

Pitting

Gears also fail by pitting. In this type of fatigue failure, repeated application of load causes small particles to flake at the surface of the tooth, leaving small depressions or pits. This is a compressive stress phenomenon, and, since the stress area in the gear and pinion are equal at the point of contact, life usually isn't balanced out for this condition. However, pitting can usually be avoided by the proper selection of materials and heat treatment.

Steel gears aren't likely to fail if the compressive stress is kept below a certain level. Usually, keeping the compressive stress below 200,000 psi prevents pitting failures. Experience with high-speed gears indicate, however, that one isn't likely to encounter the compressive stress problems normally met in conventional designs. This may be due to the rapidity of the tooth action, which does not allow the supporting oil film to break down during the time of pure rolling contact at the pitch line. In effect then, the load is applied over a greater area, reducing the compressive stress given by theoretical calculations.

Shock

Failure from shock loads takes several forms. One application of overload can cause fracture if it exceeds the ultimate strength of the tooth. Repeated application of less severe shock loads may lead to premature fatigue failure in either bending or pitting unless design allowances have been made.

Developing a balanced-life gear

The major factors to be considered in developing a balanced-life gear are:

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All of these variables are functions of both the gear geometry and its environment, and a change in any one will usually influence the others.

Design charts are available for balanced-life gears. These are based on proven design practice with steel gears. If tests show that these stress-life data are too conservative, minor adjustments will permit new stress cycle charts without obsoleting the major design curves. These charts can also be adapted for other materials. But, deriving maximum capacity from a minimum package has precluded working with the weaker materials; and little has been done with the fancy alloys, since most gears must be priced for mass production applications after they have been developed.

The charts used in preliminary balanced-life design vary both the outside diameters and the thickness of the teeth to balance the bending fatigue lives and scoring resistance of the mating gears. In addition, they assume a cutter with full radius tip generating the minimum active dedendum. This isn't allowable, however, where there is a hole bored through gears of relatively small diameter.

Chosen as a representative value for the gear was a backlash of 0.04 divided by the diametrical pitch. This is an empirical assumption which might not hold true if the load did not reverse. For reversing loads, however, it is sufficient to allow for net

changes in the length and stack-up tolerances. The variation in tooth thickness necessary to give other values of backlash would be negligible.

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Even in preliminary designs, the gear ratio is pretty well fixed by the time the gear designer is called in to express an opinion. Normally, one likes to have as few gears as possible; and one-stage gear reductions of greater than 9½ to 1 have been made.

In the past, gear designers frequently added one tooth to the gear to avoid integral gear ratios. The hunting tooth, as it was called, was added to keep the same teeth from coming into contact repeatedly. This reduced noise problems and allowed the teeth to wear in without causing too much damage. Hardened gears of extreme precision present no wear-in problems, and the hunting tooth isn't needed.

Noise is an important consideration in the selection of a gear ratio since it is desirable to avoid mesh frequencies high in the audible range. With gas turbines, this usually requires taking a large reduction in the first step. This tends to reduce power losses in the bearings due to running at high speed.

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It is generally accepted that a lower pressure angle will result in a lower capacity, quieter gear. In the past, a 14½ deg pressure angle was commonly used, but with the introduction of more accurate gear tools and the desire for smaller sizes, a 20 deg pressure angle has come into common use. In specialized applications the designer may want to use 25 deg or higher pressure angles, but these should be restricted to designs where the major consideration is capacity.

Contact ratio

Our gear design charts have been prepared for a contact ratio of 1.5. This represents a good compromise between the lower values which are usually associated with increased bending strength and the higher values which usually result in quieter gears, less likely to score. Contact ratio variations can be influenced by production tolerances, rigidity of mounting, and the number of teeth in the gears and pinions. In gears with smaller numbers of teeth, the contact ratio is more sensitive to mounting errors.

Scoring factor

The scoring factor has been described as a function of the total heat generated during the cycle of sliding from the pitch line to either the beginning or the end of tooth action. Tests have revealed a maximum allowable design scoring factor of 1½ million using mineral oil. Our tests are in general agreement with these findings, though there is room for additional testing to define this limit more accurately for high-speed gears.

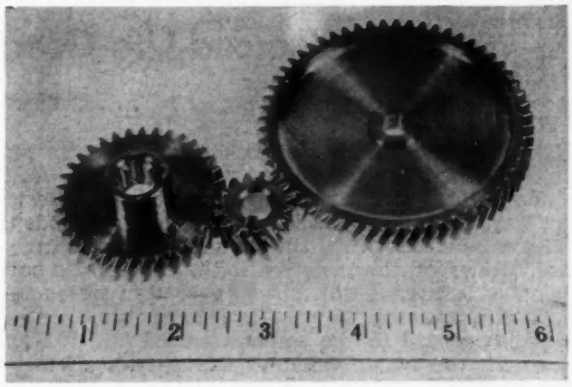

Fig. 3 — Gas turbine accessory gears, high-speed pinion in center.

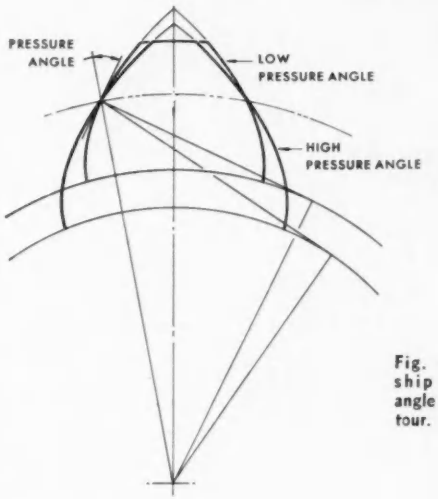

Fig. 4 — Relationship of pressure angle to tooth contour.

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Balanced-Life Gears

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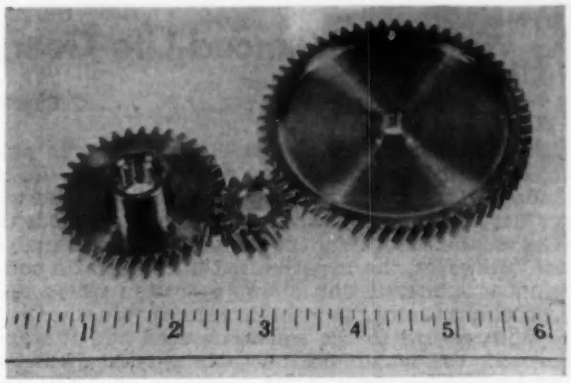

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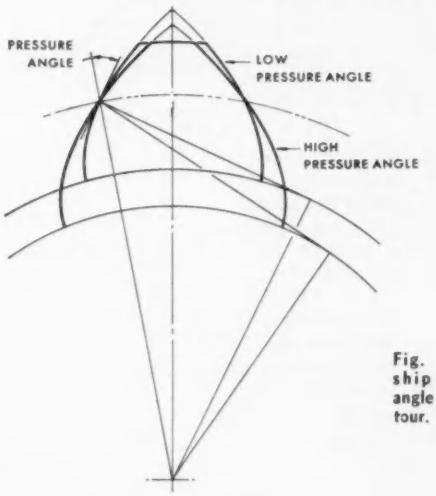

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Balanced-Life Gears

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tests to determine the stress-life relationship and to establish the stress below which the gear life is indefinitely long. These curves have been used together with one obtained from Modern Methods of Gear Manufacture[4] for the compressive stress analysis. However, the hypothesised influence of a continuous lubricant film allows operation which approaches infinite life at higher stress values.

With regard to the equations used and the approach, the maximum allowable outside diameter as limited by the scoring factor is first defined. Using Straub's equation for scoring factor, begin with these two equations:

$$PVT_p = 19.984 \frac{(1+r)^{\frac{3}{2}}}{r} \sqrt{\frac{\sin\phi}{CR\cos\phi}} \frac{L_p^2}{\sqrt{\rho_p \rho'_g}} \sqrt{\frac{T_p}{F}}\, n_p \qquad (1)$$

$$PVT_g = 19.984 \frac{(1+r)^{\frac{3}{2}}}{r} \sqrt{\frac{\sin\phi}{CR\cos\phi}} \frac{L_g^2}{\sqrt{\rho'_p \rho_g}} \sqrt{\frac{T_p}{F}}\, n_p \qquad (2)$$

where: PVT = scoring factor
r = gear ratio
CR = contact ratio
ϕ = pressure angle, deg
L = length of action from pitch point to OD, in.
ρ = radius of curvature at point of contact at top of tooth, in.
ρ' = radius of curvature at point of contact at bottom of tooth, in.
F = face width, in.
T = torque, lb-in.
p = pinion
g = gear

Equating the scoring factor at the outside diameter of the gear to the scoring factor at the outside diameter of the pinion, it is possible to cancel out all but the following factors: $\frac{L_p^2}{\sqrt{\rho_p \rho'_g}} = \frac{L_g^2}{\sqrt{\rho'_p \rho_g}}$ (3). In these equations $(L_p + L_g)$ is equal to the active length of contact between the two gears (Fig. 5). If a value is assumed for either L_p or L_g, it is possible to solve for all other factors in equation (3), and by inspection make a more accurate second assumption for L_p. Interpolation between the two values of L_p will lead to a pair of gears with equal scoring factors. Returning to equation (1) or (2), the proper face width for the gears can be determined. By successive trials the scoring life can be balanced.

Next, the bending stresses are balanced. A pinion bending stress must be found which gives a gear life in cycles inversely proportional to the gear ratio. Thus, a condition is specified where both gear and pinion reach their endurance limit in bending at the same time.

All major gear dimensions have been determined at this point except the tooth thickness. One factor which has been established is the circular pitch, which is the pinion tooth thickness, plus the gear tooth thickness, plus the backlash. The assumed value for the backlash can be subtracted from the circular pitch to get the sum of the two tooth thicknesses. Successive values for tooth thickness are then assumed until one that gives equal bending stress fatigue life is obtained.

Suppose that it is assumed that the two teeth are of the same thickness. A tooth form factor (X) can be determined graphically from a gear layout (Fig. 6). In practice, however, it is simpler to do this by analytical methods on a computer. Before proceeding, it should be verified that the tooth thickness is not such that it will result in a pointed tooth. The bending stress of the pinion can be calculated from:

$$s_p = \frac{3\pi T_p}{F N_a N_p X} \qquad (4)$$

where: s_p = bending stress of pinion, psi
T_p = torque, lb-in.
F = face width, in.
N_a = length of action, in.
N_p = number of teeth, pinion
X = tooth form factor, in.

A similar equation will give the stress in the gear.

A ratio of tooth thickness now may be assumed and the stress calculated for this condition. A graph is plotted showing the ratio of the tooth form factors of the gear and pinion versus the tooth thickness of the pinion. From the equation:

$$\left(\frac{X_p}{X_g}\right)^{5.126} = r\left(\frac{F_g}{F_p}\right)^{5.126} \qquad (5)$$

where: X_p = tooth form factor of pinion, in.
X_g = tooth form factor of gear, in.
r = gear ratio
F_g = face width of gear, in.
F_p = face width of pinion, in.

which gives the optimum ratio of tooth form factors, the value of the optimum pinion tooth thickness can be determined from the plot.

The gearset now has both balanced scoring life and bending fatigue life. One more check remains before the design is complete — the evaluation of compressive stress. This computation is based on the Hertz equation for two cylinders in contact along a common element. From this equation the compression stress at the pitch line of steel gears can be derived, assuming that one tooth is in contact.

It may be that the compressive stress is too high to give satisfactory operation. A safe level for the desired level can be determined by the following equations:

$$s_c = 2290 \sqrt{\frac{T_p}{R_p^2 \cos\phi \sin\phi F}\left(1 + \frac{1}{r}\right)} \qquad (6)$$

where: s_c = compressive stress, psi
R_p = pitch radius of pinion, in.
F = face width, in.
T_p = torque of opinion, lb-in.
ϕ = pressure angle, deg
r = gear ratio

If this determination indicates an unsatisfactory stress level, it may still be possible to avoid recalculating the entire design. This requires the use of another face width which will reduce the stress to a satisfactory level and still result in a gear of reasonable proportions. If the maximum usable

[4] Pub. by National Broach & Machine Co., Detroit, 1950.

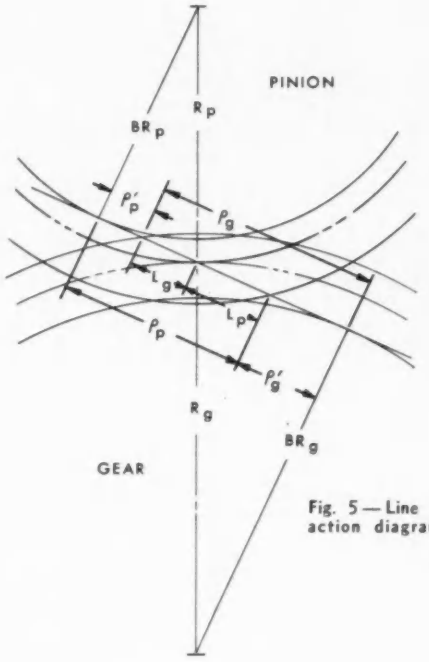


Fig. 5 — Line of action diagram.

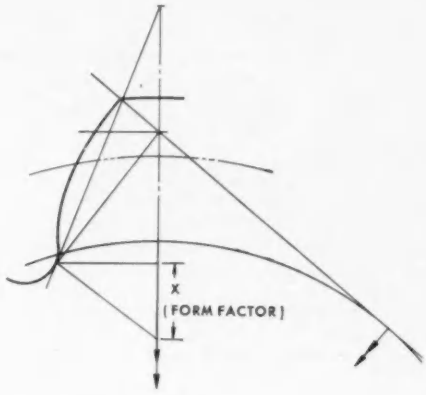


Fig. 6 — Tooth form factor.

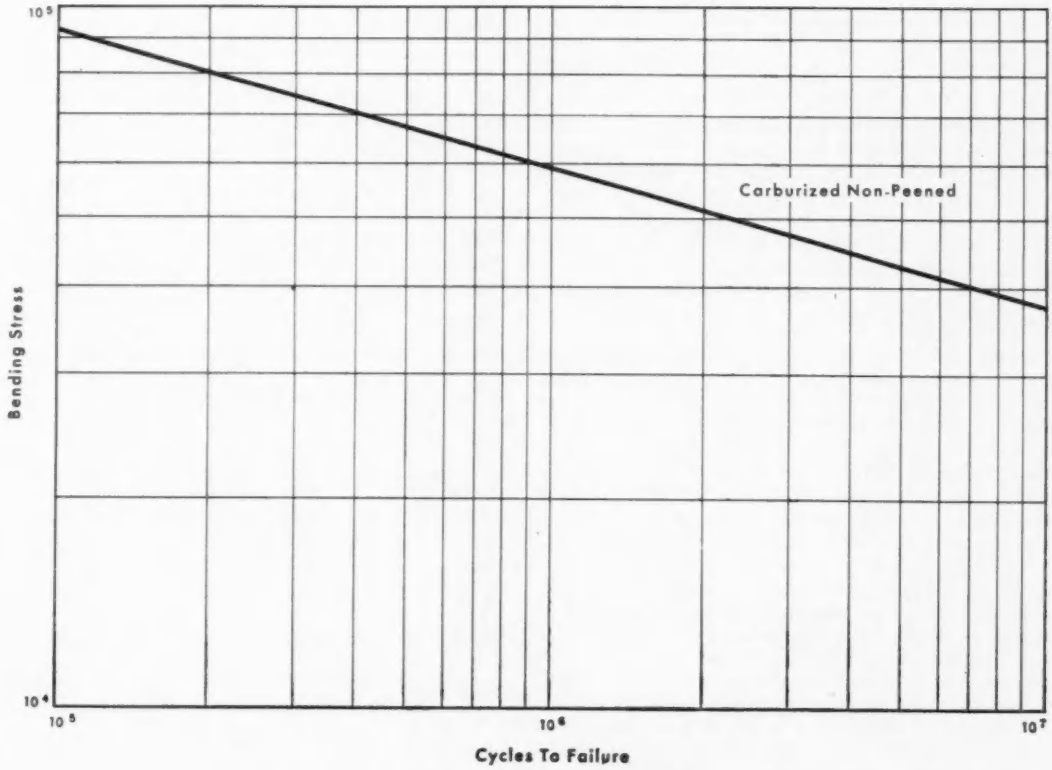


Fig. 7 — Durability of automotive gears — bending fatigue chart.

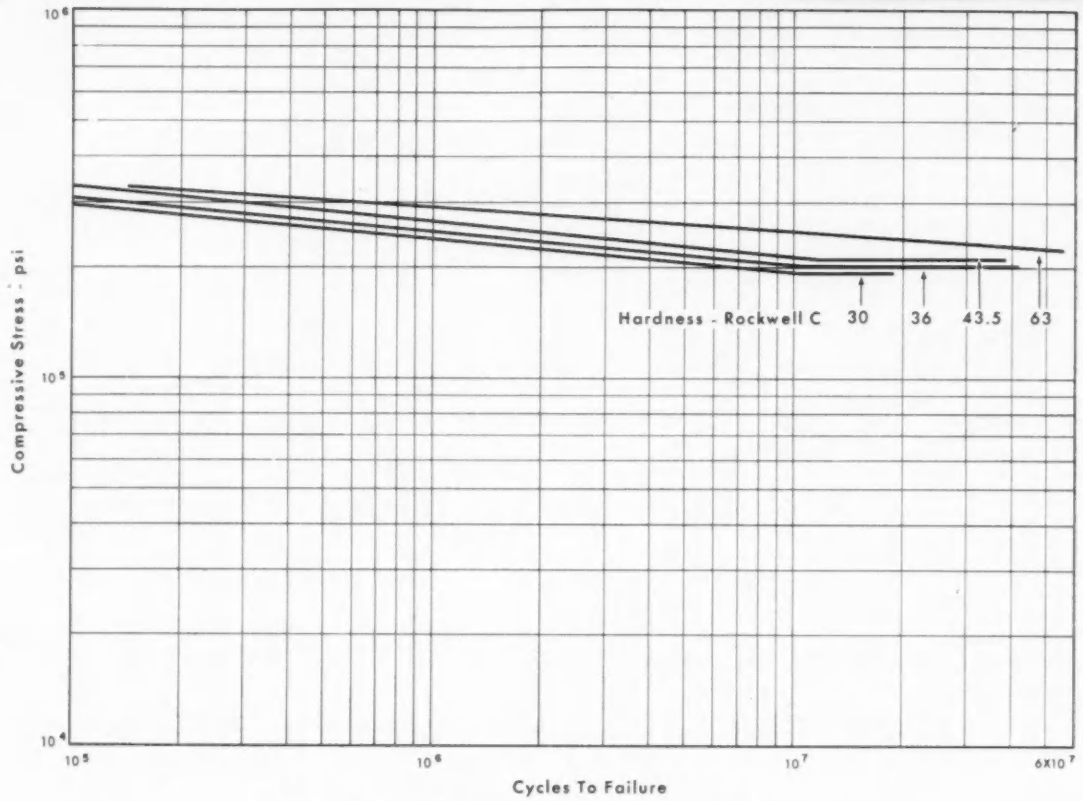


Fig. 8 — Surface durability of gears — compressive fatigue chart.

Balanced-Life Gears

. . . continued

face width still results in a compressive stress which is too high, it is necessary to go back to the beginning and assume a new value which will increase the radii of the equivalent cylinders at the pitch point. This can be done by increasing the center distance of the two gears or by increasing the pressure angle and maintaining the same center distance.

Computer programming

The equations that have been balanced are made up of two types of factors. The first group consists of the physical characteristics of the gears themselves. The second group's characteristics have to do with conditions under which the gears will operate. These equations can be rewritten to equate the gear geometric characteristics to the operating characteristics in each case. When this has been done, a program can be prepared for a digital computer which will work through the complete calculations for a set of balanced-life gears. In effect, the computer is given the description of the gear, its diametral pitch, number of teeth, contact ratio, pressure angle, and gear ratio. It is then instructed to solve for the nongeometric values for both a balanced scoring life and a balanced bending stress life. A range of values for each of the geometric characteristics is selected, and the computer grinds away solving the problems.

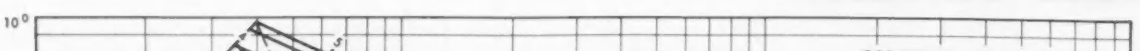
The tables that have come out of this program are, in effect, a list of presolved balanced-life calculations. All of the calculations that were done on the computer are the same as would have been done in a manual program. The computer gives values in terms of a constant so that each of the factors can be plotted on a grid. All the nongeometric functions of bending stress form the ordinate, and all the nongeometric functions of scoring form the abscissa.

Only one complication remains at this point. The data requires a three-dimensional chart, and three-dimensional charts are hard to get on two-dimensional paper. To avoid this extra dimension, the face width factor is taken out of the geometric functions and placed on the other side of the equation, so that it appears as part of the coordinate system. The charts were constructed for a face width of 1 in. The value obtained using this face width can be converted to any other reasonable face width by the application of a simple nomograph.

The complete program is such that the computer can always be given instructions to solve any balanced-life gear problem. There are two drawbacks, however: (1) Computer time may not be immediately available when it is needed to make quick analyses; (2) the computer cannot separate unreasonable solutions which are due to conditions other than those in the basic gear design equations. For a versatile program it has been better to make the machine calculations and inspect them later for anomalies, rather than to list all possible pitfalls, together with methods of avoiding them.

A similar approach was used for obtaining compressive stress charts. Once again, the face width was moved from the geometric side of the equation to simplify plotting.

Figs. 9–14 are a family of charts which were used



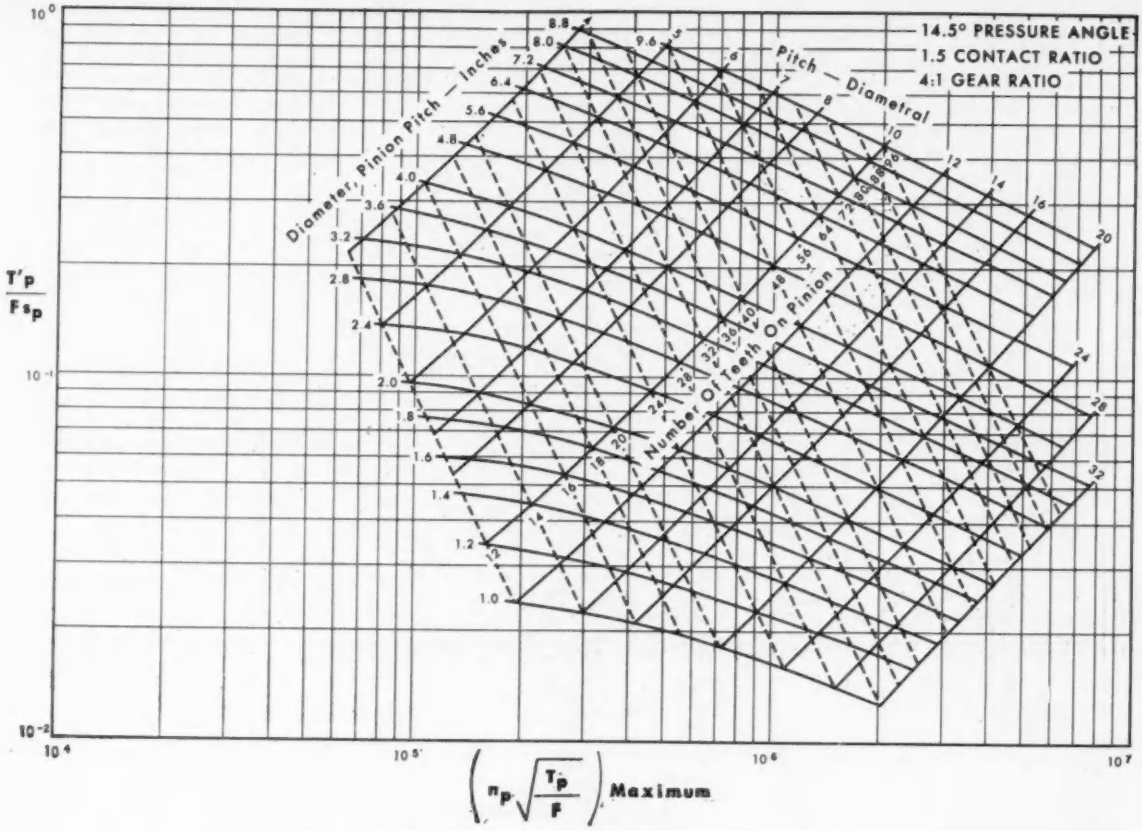


Fig. 9 — Balanced-life gear design chart, 14½ deg pressure angle.

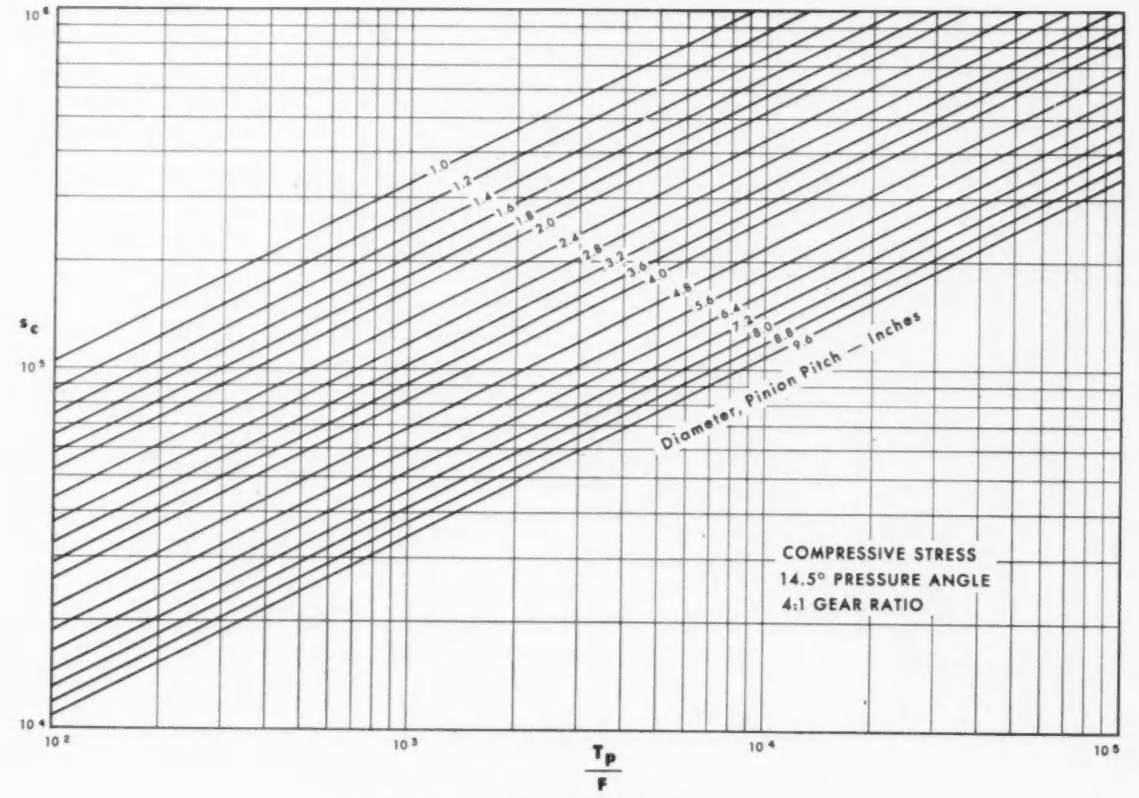
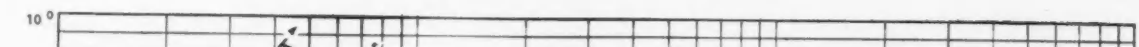


Fig. 10 — Compressive stress chart, 14½ deg pressure angle.



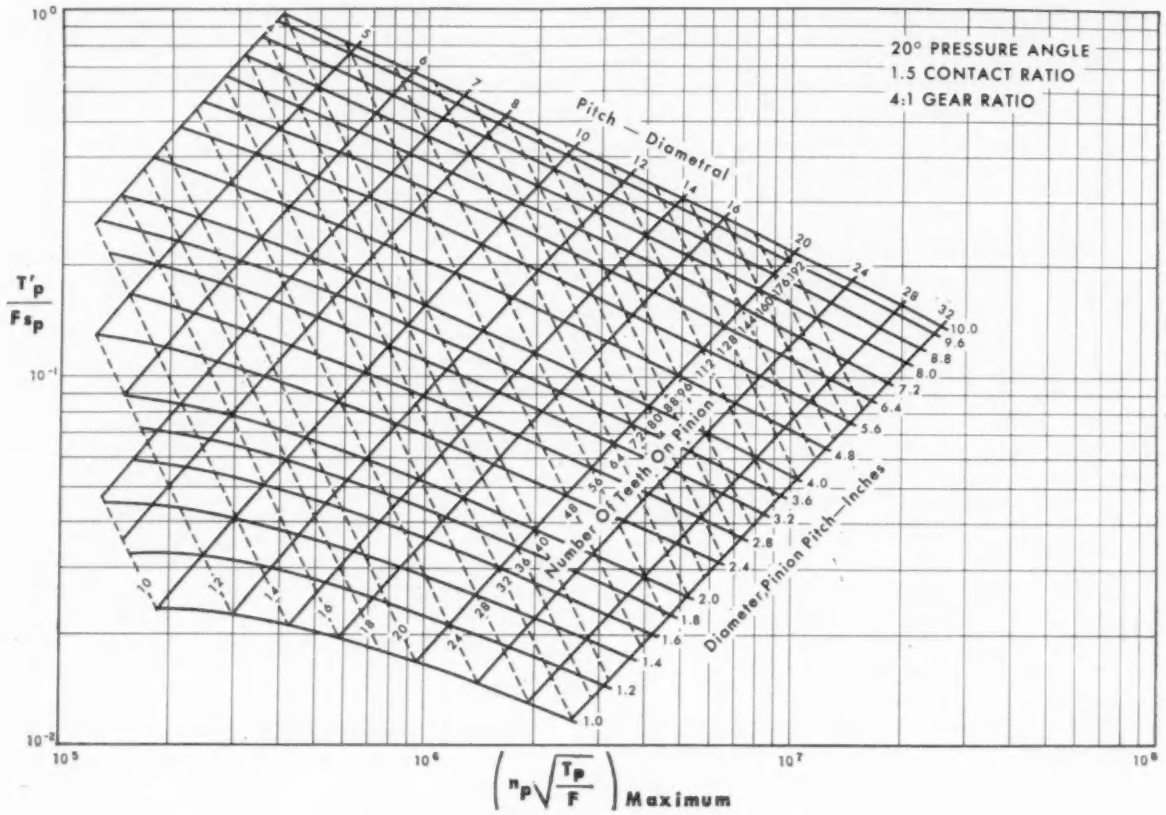


Fig. 11 — Balanced-life gear design chart, 20 deg pressure angle.

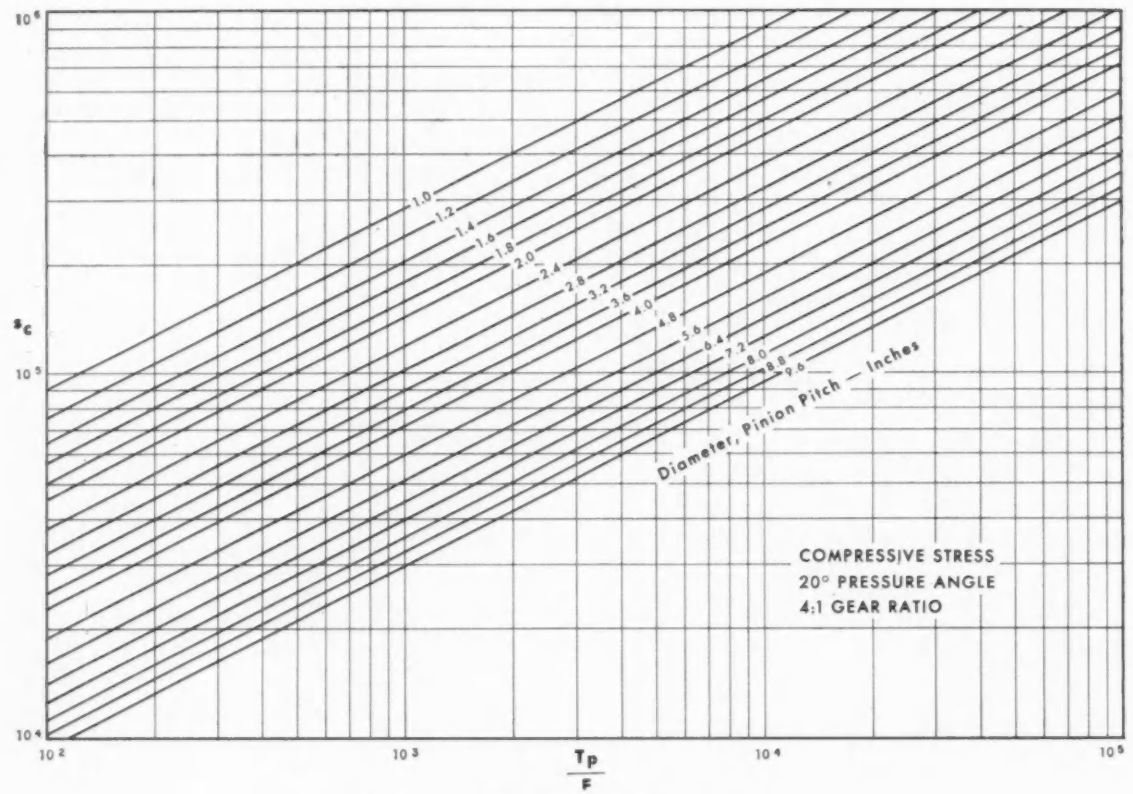


Fig. 12 — Compressive stress chart, 20 deg pressure angle.

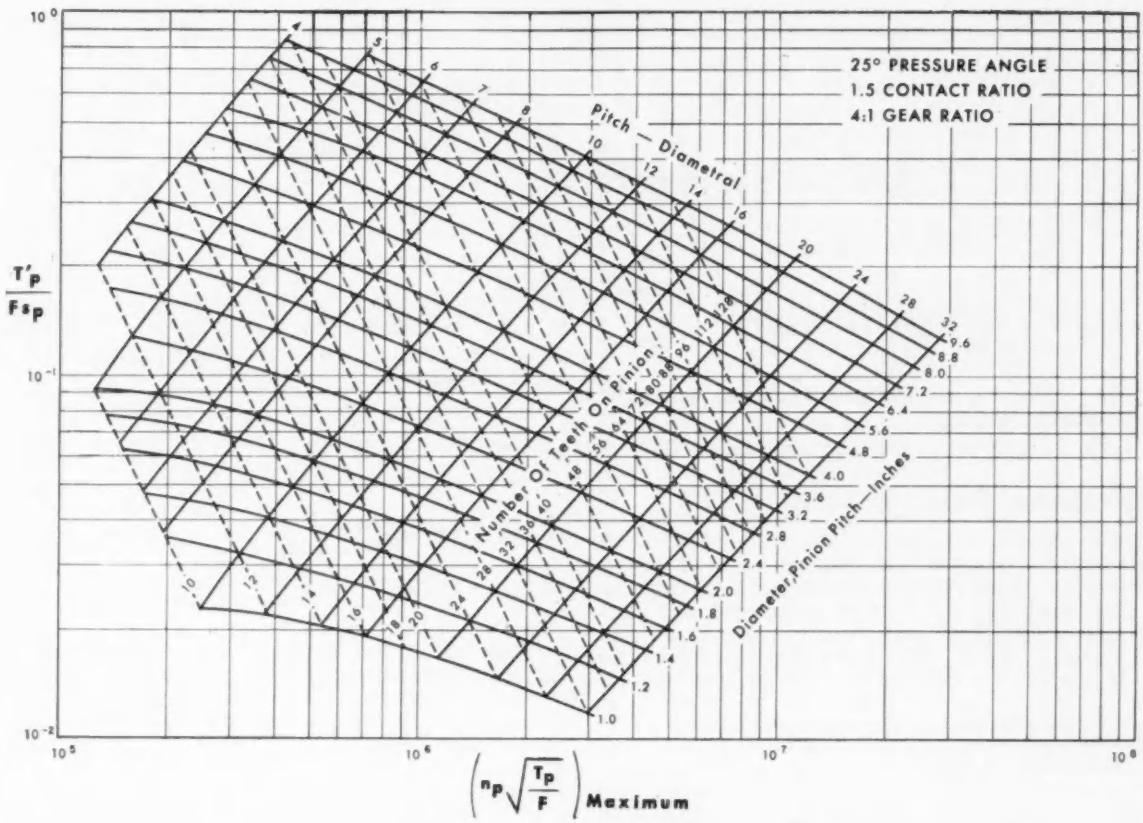


Fig. 13 — Balanced-life gear design chart, 25 deg pressure angle.

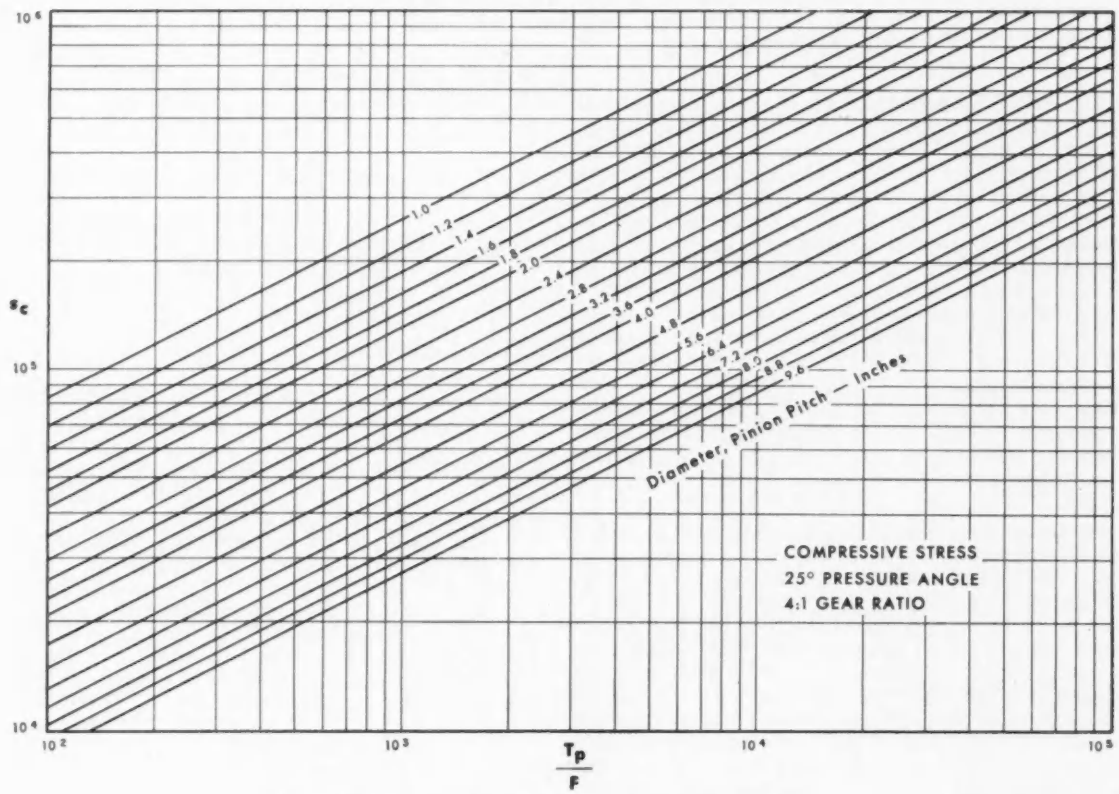


Fig. 14 — Compressive stress chart, 25 deg pressure angle.

(Continued on next page)

Balanced-Life Gears

. . . continued

to solve a number of spur gear problems using the balanced-life concept.

Typical gear design problem

Let's examine a typical gear design problem to show how some of the charts might be used.

For a preliminary design, the engineer will usually be furnished with the gear ratio, approximate center distance, and the conditions under which the gear must operate. For example, assume that the following specifications have been established:

ratio	4/1 reduction
approximate center distance	5 in.
operating conditions	no extremes of temperature medium viscosity mineral base oil negligible shock loading torque-speed curve

From this and other information in the general specifications, it is possible to determine the design life for bending and compressive stresses. The operating conditions under which gear life will be specified must now be selected. In the example, this was estimated by the designer to be two million cycles at a higher-than-normal sustained operating torque of 42.3 lb-ft. Based upon this, an allowable bending stress of 52,000 psi was determined for a carburized nonpeened gear with a hardness of R_c 60. This information is taken from the bending stress-cycle chart (Fig. 7), a fatigue chart based on experimental data.

The next step is to find, from the torque-speed curve in the specifications, the conditions at which maximum tendency to score will occur. This is the point where a maximum value is reached for the factor, $\sqrt{T_p}\ n_p$. (T_p = torque of pinion in lb-in.; n = rpm), in this case 219 lb-in. of torque at 45,000 rpm. The scoring factor at this point on the curve should not exceed 1,500,000. Gear design charts can now be selected (Figs. 9–14). Because a pressure angle of 20 deg would be satisfactory for this application, this narrows the selection to a single pair of charts (Figs. 11 and 12) with 20 deg pressure angle, 4/1 reduction, and 1.5 contact ratio. Values of ordinate and abscissa are now calculated in order to enter the gear design chart. For gears of this type, a tentative value for face width of 0.5 in. seems reasonable. This initial assumption isn't too critical because it can be easily varied.

For the ordinate:

$$\frac{T'_p}{Fs_p}\frac{507}{0.5\ (52{,}000)} = 1.95 \times 10^{-2}$$

where: T'_p = torque at bending design life, pinion, lb-in.
F = face width, in.
S_p = bending stress, pinion, psi.

Any point on the grid having an ordinate value of 1.95×10^{-2} or above will meet or exceed the requirements for these conditions of bending.

For the abscissa:

$$n_p \sqrt{\frac{T_p}{F}} \frac{\text{Design Scoring Factor}}{10^6} =$$

$$45{,}000 \sqrt{\frac{219}{0.5}}\ (1.5) = 1.41 \times 10^6$$

where: n_p = rpm, pinion
T_p = torque of pinion, lb-in.
F = face width, in.

Any value on the chart which is to the right of a vertical line drawn through 1.41×10^6 will satisfy the requirements for scoring factor.

For these conditions, a pinion of 0.5 in. face width described at the intersection of the two lines, has a pitch diameter of about 1.2 in. and a diametral pitch of approximately 22.

(Experience indicates that a gear of this diametral pitch would present problems in manufacture. It might crack in heat-treating and the grinding wheel needed would be so fine as to create problems in tool life.)

From the required center distance, the proportions of pitch diameters can be established from the equations:

$$CD = \frac{D_p + D_g}{2}$$

and:

$$D_g = rD_p$$

where: CD = center distance
D_p = pitch diameter of pinion, in.
D_g = pitch diameter of gear, in.
r = gear ratio

which yield a value of: $D_p = 2$ in.

This value shows that the pinion pitch diameter previously obtained from the chart does not meet all of the requirements. Knowing that the pinion pitch diameter should be 2 in., the face width nomograph (Fig. 15) can be used to correct this situation. By aligning it properly and placing it on the chart so that the point, $F = 0.5$ in., coincides with the point previously plotted for $F = 0.5$ in. it is possible to read a new value for face width where the nomograph scale intersects the 2 in. pitch diameter curve. This allows the designer to obtain an optimum configuration which meets center distance requirements. From the chart at this point, the following characteristics of the pinion may be read:

pinion pitch diameter	= 2 in.
diametral pitch	= 20
number of teeth	= 40
face width	= 0.26 in.

Using the companion compressive stress chart (Fig. 12) proper values may be substituted, and a value for the abscissa determined.

Locating this value on the abscissa, a vertical line is drawn which intersects the line for a pinion pitch diameter of 2 in. From this intersection, a compressive stress value of 200,000 psi is read on the ordinate.

Referring to the compressive stress-cycle chart (Fig. 8), it can be seen that the life will be greater than the two million cycles originally specified and pitting will not occur.

Using conventional gear formulas, dimensions of the mating gear are established.

Experience has shown, for purposes of preliminary layout, it is reasonable to assume a value for the addendum of the pinion and gear equal to the reciprocal of the diametral pitch to obtain complete dimensions for a layout.

This completes the preliminary design of the gearset. Using the equations which formed the basis for the charts, the gear designer can determine the detail dimensions required for the final gear design.

To Order SP-172 . . .
from which material for this article was drawn, see p. 6.

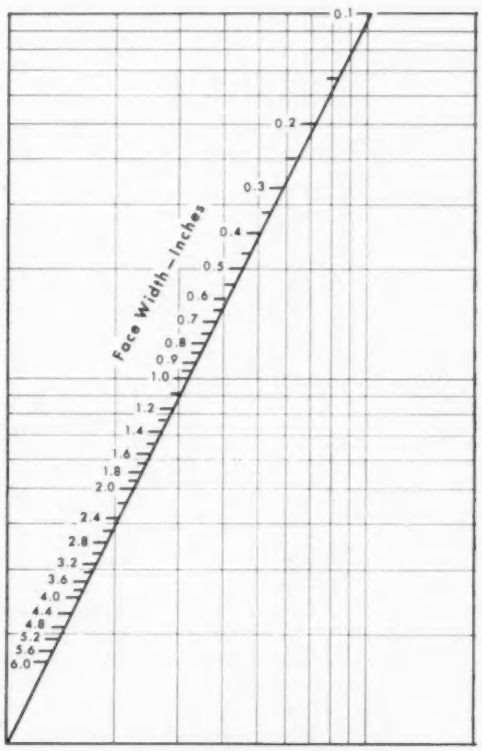


Fig. 15 — Nomograph for various face widths.

Help Wanted!

. . . from engine men

How do you make a decision on engines when you can't get experimental verification? That is the problem of SAE's Nomenclature Subcommittee in preparing a Recommended Practice for numbering engine cylinders . . . and help is wanted.

The desire for a standard on cylinder numbering and engine rotation is long standing. Throughout the years various engine builders have used acceptable but different conventions, which have caused misunderstandings between users of passenger-car, marine, and stationary engines.

The subcommittee is proprosing the following conventions in an attempt to cover the majority of cases where specifications are of reoccurring importance:

SAE Standard Rotation

Counterclockwise rotation viewed from the principal output end. If power can be delivered from both ends, the flywheel end shall be used.

Opposite Rotation

Clockwise rotation viewed from principal output end.

Cylinder Numbering

Cylinders shall be numbered by either one of two methods:

a. Numbered in the sequence, in which the connecting rods are mounted along the crankshaft beginning with the cylinder farthest from the principal output end.
b. In multibank engines, cylinders are numbered in sequence in each bank, starting with the farthest cylinder, designating right or left bank as viewed from the principal output end. An appropriate suffix letter, such as "R" or "L" shall be used.

Recognizing that these conventions are somewhat arbitrary, the Nomenclature Subcommittee would like to know how well they would be accepted if presented as a Recommended Practice for the SAE Handbook.

Please give your reaction by writing to Chairman:

Carl Meile
International Harvester Co.
5225 S. Western Blvd.
Chicago 9, Ill.

Designing the Control

Space Reentry

A neutrally stable control loop in the most sensitive control and eliminates the need

Based on paper by

William Beauchemin

Bell Aircraft Corp.

CONTROL SYSTEMS for space reentry vehicles must overcome dynamic pressure variations of 100/1 and aerodynamic moment coefficient changes of 4/1 if the pilot is to experience uniform handling characteristics throughout the flight regime. To accomplish this uniformity of handling, an adaptive circuit must be designed which constantly changes the control system gain in line with the changing flight regime.

Adaptive circuits basically perform three functions. They periodically create a test signal, then compare the response of the system to the desired response, and finally vary a parameter in the system in the direction of the desired response.

The first of these steps can be simplified if the control system itself can be made to produce the test signal rather than having separate signal generating equipment. One solution is to adjust the parameters of the control loop so the loop is neutrally stable. A sustained oscillation results which can be used as a test signal. Any change in the amplitude or frequency of this oscillation reflects a change in the aerodynamic or structural characteristics of the reentry vehicle.

A block diagram of such a circuit is shown in Fig. 1. The difference between the command and the actual attitude of the vehicle is fed to a network (model) having the bandwidth and damping characteristics required for the vehicle. The output of this network is fed to the rate loop of the system, which includes the aero-structural dynamics of the vehicle, the rate gyro, the actuators for the control surfaces, and a variable gain device driven by the adaptive circuit. By setting the rate loop gain at its neutrally stable point (gain at which output lags input by 180 deg), the bandwidth of the rate loop can be made sufficiently greater than that of the model to ensure flat response to all signals coming from the model.

It is desirable to have the frequency and amplitude of the neutrally stable loop as low as possible to minimize wear, conserve control power, and maintain the pilot's physiological comfort. However, the frequency should be high to ensure that the adaptive control system and adaptive circuit bandwidth requirements are met. For the vehicle considered, a gain cross-over frequency of approximately five times the model bandwidth appears to satisfy these criteria. Also, the amplitude of the oscillation should be five times greater than the control system threshold to make sure that the adaptive circuit is monitoring the linear gain and not the gain resulting from operation in the deadzone or noise region. This means that the deadzone of the control system must be carefully designed if it is to protect the pilot from excessive vibrations at low-level, high-speed flying conditions. For example, rate gyro thresholds of less than 0.002 deg per sec are required if the vibration limit for humans is not to be exceeded at vehicle velocities approaching 10,000 fps.

The output of the rate sensor is used to measure and control the amplitude of the characteristic oscillation. This avoids the disadvantages of using the amplitude of the control surface deflection and the resulting excessive pilot vibration and vehicle stresses. In order to reduce the adaptive circuit's sensitivity to low-frequency commands and gusts, a filter having a bandpass above the model response is included as part of the circuit. The bandpass of the filter is designed to permit the adaptive circuit to sense instabilities which might occur from unpredictable variations in such parameters as servo-

System for a Vehicle

the yaw circuit provides

for a test signal generator.

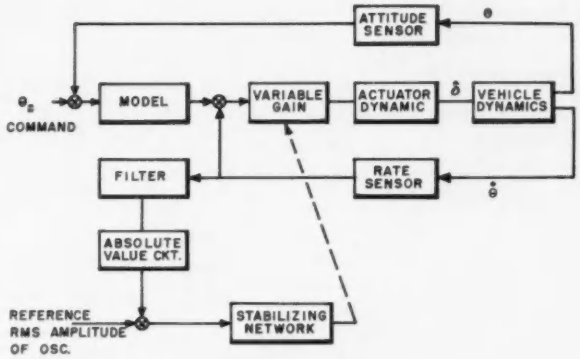


Fig. 1 — Attitude control loop and adaptive circuit.

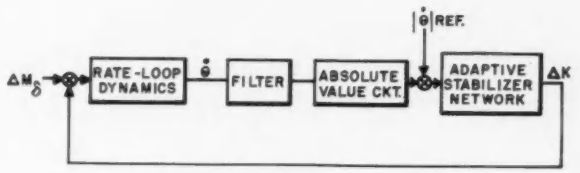


Fig. 2 — Adaptive circuit loop.

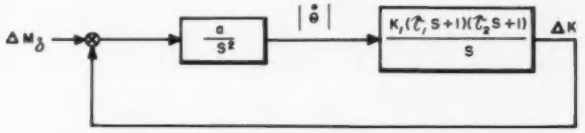


Fig. 3 — Linearized adaptive circuit loop.

actuator and structural damping modes. The filter can also be designed to minimize the high-frequency effects of vibrations from auxiliary equipment which may be picked up by the rate gyro.

A linear gain device was chosen for the vehicle considered. It is independent of the amplitude of the input command.

Adaptive circuit gain changing loop

A block diagram of the adaptive circuit loop is shown in Fig. 2. The error between the change in loop gain resulting from parameter variations and that produced by the adaptive circuit acts on the rate loop dynamics to change the amplitude of the characteristic oscillation. The filter passes signals whose frequencies are above those of the model. The output is fed to an absolute value circuit or depolarizer whose output is a d-c voltage which is the rms value of the filter output. The difference between this rms value and a bias voltage which represents the desired rms amplitude of oscillation is used to drive the gain changing device through a stabilizing network.

To analyze this loop, the transfer function of the block depicting the rate loop dynamics must account for the change in amplitude of the characteristic oscillations with changing loop gain. An exponential relationship:

$$\dot{\theta}=\dot{\theta}_0 e^{a\Delta K t}$$

where:

$\dot{\theta}$ = Angular attitude rate, radians per sec
a = Constant, describing exponential rate of characteristic oscillation
ΔK = Incremental change in gain
t = Time, sec

results from simplified airframe equations.

This equation can be linearized by considering

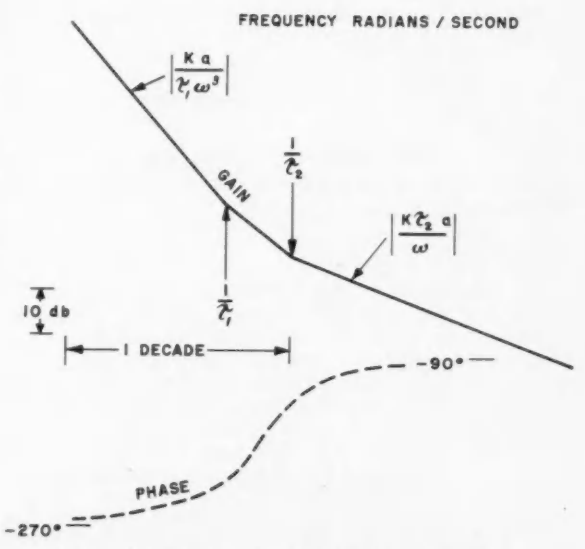


Fig. 4 — Gain and phase characteristics of the adaptive loop.

Space

Reentry

Vehicle

. . . continued

small perturbations about the neutrally stable gain. This assumption seems reasonable since the adaptive circuit is designed to be fast enough to maintain the system at its neutrally stable point for the maximum rates of change expected in the flight control system loop gain. Steady state errors are washed out by an integration in the stabilizing network. With this assumption, a linearized transfer function of rms amplitude of oscillation as a function of gain change is obtained which can be used to replace the rate loop dynamics in the mathematical model.

The adaptive circuit loop can be represented by the mathematical expressions shown in Fig. 3. The response bandwidth and stability of this loop are established by the design of the stabilizer network, $K_a(S)$.

The characteristic equation of this simplified loop shows that the adaptive circuit network must be in the form of an integration and a second order lead for stability.

$$K_a(S) = \frac{K_1(\tau_1 S + 1)(\tau_2 S + 1)}{\tau_1 S}$$

where:

K_a = Gain of adaptive loop
$\tau_{1,2}$ = Adaptive loop lead time constants, sec
S = LaPlace operator
$\frac{K_1}{\tau_1}$ = Gain of stabilizer network

An open loop Bode plot of the adaptive circuit is shown in Fig. 4. The accuracy requirements (which limit the allowable amplitude of oscillation which can be tolerated during maximum rates of change of the rate loop gain) establishes the cross-over frequency to be:

$$\omega_a = a\tau_2 K_1$$

and for stability it is desirable to make $\omega_a \geq 2\left(\frac{1}{\tau_2}\right)$ and $\tau_1 > \tau_2$.

An analog simulation of the adaptive circuit and attitude control loop proved the feasibility of the design.

Choosing the channel

The amplitude of the control surface oscillations in the yaw channel proved to be four times greater than in the pitch channel for the same control power consumption and vibration of the pilot. Since the flight dynamics are about the same in all channels (pitch, roll, and yaw), it is feasible to vary all the gains of the system by monitoring the characteristic oscillations of the yaw loop only. This gives the highest neutral stability gain which is good from response considerations.

To Order Paper No. 171A . . .
from which material for this article was drawn, see p. 6.

Upside-down levapad makes a new wind tunnel scale

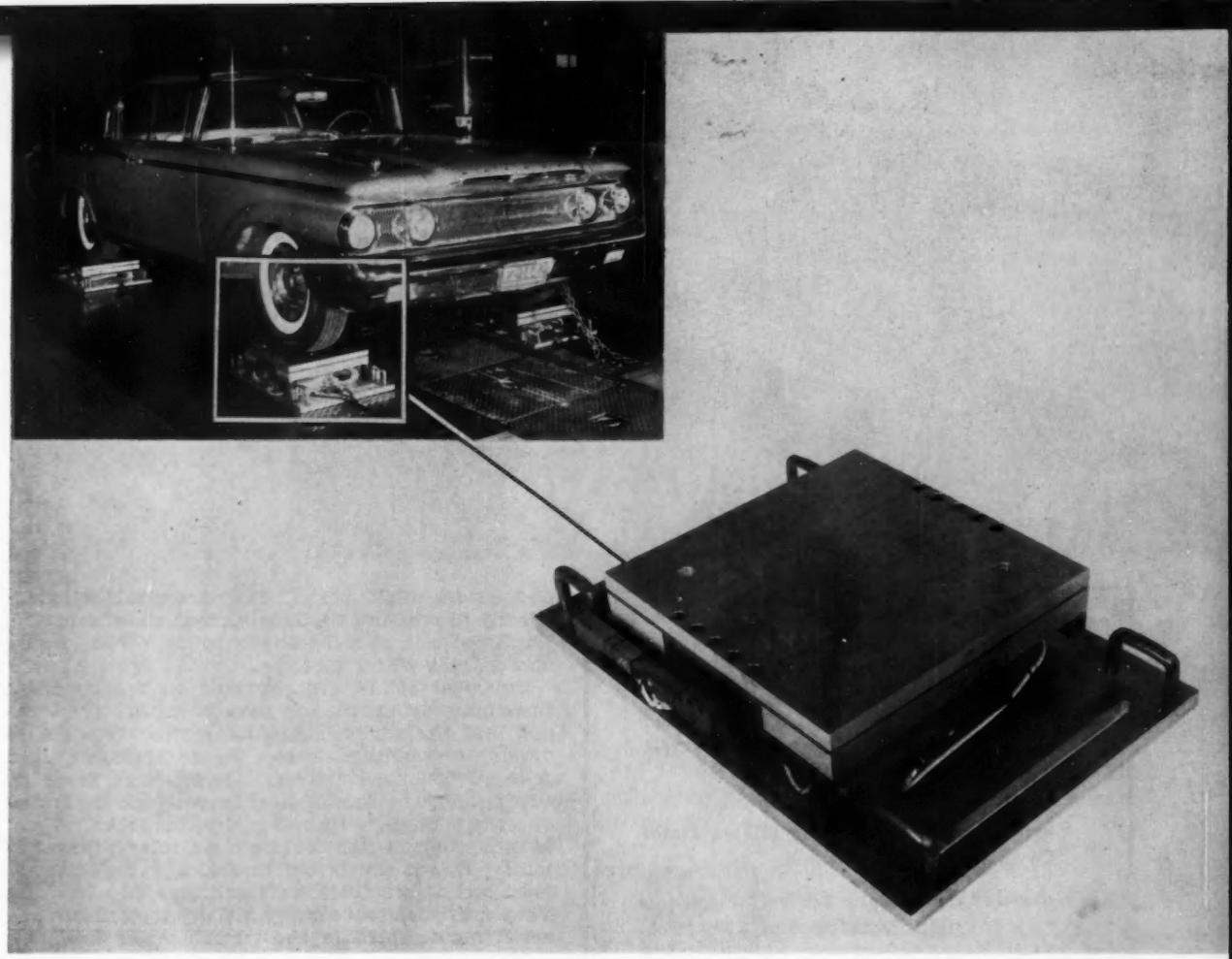
▸ The floating action of the film of air in all directions. The design produces

Based on presentation by **Joseph F. White** Ford Motor Co.

FLOATING cars on an upside-down levapad proved to be a cheap but accurate way to measure aerodynamic forces in Ford's wind tunnel. This technique has three major advantages for the engineer who wants to add a balance system to an existing tunnel. They are:

- The tunnel does not have to be torn apart or shut down.
- The cost is much lower than conventional systems and has comparable accuracy.
- The installation is portable and quickly set up.

Watching vehicles day after day on test in a fine wind tunnel that does not have aerodynamic scales is a strong incentive to develop economical portable scales. The major problem is to provide a mechanism that will support the full weight of the vehicle and offer negligible resistance to horizontal motion of the vehicle. It took quite a while to recognize that this problem matched the functional definition of a levapad. Levapads were developed for the frictionless support of moving vehicles, but they work just as well under static conditions "floating" heavy loads on a film of flowing air a few thousandths of an inch thick.



in a levapad can support a car and still give accurate force readings

a compact, inexpensive, portable balance system for vehicle wind tunnels.

Under each wheel there is a levapad, and a system of electric load cells (strain gages) that measure the vertical, longitudinal, and lateral reaction of the wheel it supports. From these forces and the geometry of the layout, the three forces and three moments acting on the car can be calculated by simple arithmetic,

The construction of one of these scales is shown in Fig. 1. The levapad is inverted from its usual position and mounted on a base plate. The vertical wheel reaction is measured by a scale that floats on the levapad. The scale consists of two plates separated by four electric load cells. The cells are of the resistance strain gage variety and are connected electrically to produce a single voltage proportional to the vertical wheel reaction.

The important feature of these load cells is that they can transmit horizontal aerodynamic forces to the horizontal load cells in addition to performing their primary function of measuring the vertical force. This permits a compact, solid construction with no levers or pivots.

The horizontal forces are measured by similar load cells. Three cells are required to link the vertical weight scale and base plate, and to restrain the vertical weight scale to a central position on the levapad. Two of the cells are parallel and on op-

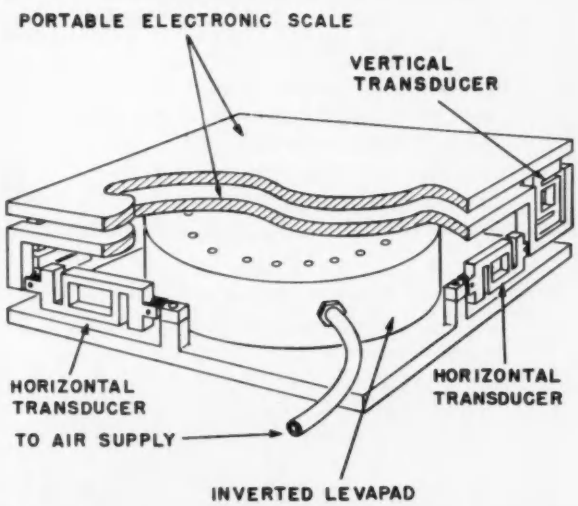


Fig. 1 — Schematic drawing of aerodynamic scale which uses a levapad to support the weight of the vehicle.

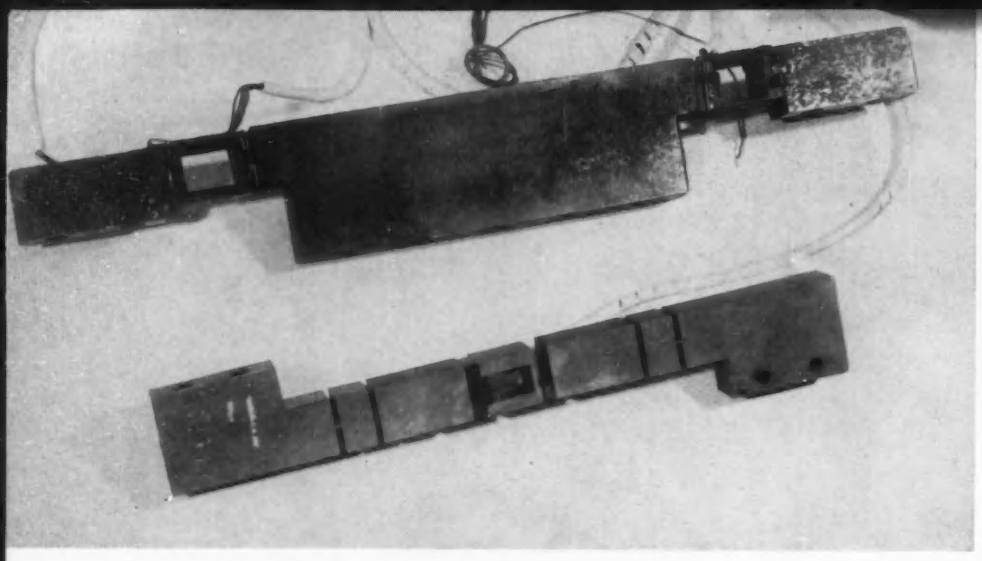


Fig. 2 — Universal joints made of two thin steel webs at right angles are used to decouple force measurements in three directions. This isolation is necessary because of the slight motions associated with strain gages and the levapad.

This article is based on material drawn from SP-180. This special publication is the symposium on Automobile Aerodynamics presented during SAE National Automobile Week.

The SP contains:

- **Early Wind Tunnel Testing at Ford Motor Co.** by A. H. Esper, Ford Motor Co.
- **Vehicle Model Laws:** a. General Similarity b. Fluid Mechanics Models by P. R. Kyropoulos, K. B. Kelly, and William Tanner, Styling Staff, GMC
- **Wind Tunnel Models and Techniques** by K. B. Kelly, Styling Staff, GMC
- **Evaluation and Interpretation of Data** by William Tanner, Styling Staff, GMC
- **New Techniques for Full-Scale Testing** by J. F. White, Ford Motor Co.
- **Summary and Outline of Future Problems** by P. R. Kyropoulos, K. B. Kelly, and William Tanner, Styling Staff, GMC

Fig. 3 — Upside-down levapad acts as a frictionless float for an aerodynamic scale. The only wind tunnel modification necessary with this type scale are holes in the floor for the one air hole and three electrical connections.

posite sides of the scale. They are combined electrically to measure the longitudinal wheel reaction. The third cell, at right angles to the others, measures lateral wheel reaction.

Universal joints are provided to accommodate the slight vertical motion associated with the levapad and the slight horizontal motion required to develop measurable stresses in the horizontal load cells. Frictionless universal joints were made by cutting into the bars of steel from which the transducers are made to form thin flexible webbs. A pair of these webs at right angles constitutes a universal joint. This is illustrated in Fig. 2. The universal joint webbs are 0.060 in. thick and 0.10 in. long. They must be stout enough axially to transmit the aerodynamic force to the transducer or load cell. Both tension and compression forces are encountered. The webbs must also be flexible enough in bending to offer low resistance to the levapad motion (0.006 in.) and the horizontal motion encountered in deflecting the right angle transducer (0.003 in.). There is adequate latitude between these requirements of stoutness and flexibility that the dimensions of the webb are not critical. However, the scales are calibrated when completely assembled since the webbs still do constitute a small portion of the elastic force-measuring system.

The transduced design is also shown in Fig. 2. It is a set of parallel beams. This is superior to a single beam type in that the transducer is rigid in bending and the beams deflect in a controlled parallelogram type motion.

The levapad itself, shown in Fig. 3, is 14 in. in diameter. It has 16 air exit holes equally spaced on a 4 11/16 in. radius, with four holes equally spaced on a 1 9/16-in radius. All holes are 0.050 in. in diameter. With a load of 1000 lb on a scale and 70 psi air pressure, the air gap over the levapad is 0.006 in. This is adequate to be certain that there is no contact between surfaces due to irregularities or warping. The air consumption is approximately 20 cfm. Higher flotation could be achieved by drilling out the exit holes, but this would put a drain on the building air supply.

The projecting pins are locking devices that relieve the horizontal load cells of the shock loads incurred in moving vehicles on and off the scales.

To order SP-180 . . .
from which material for this article was drawn, see p. 6.

New Techniques Control

Noise and Vibration in Unitized Cars

Based on paper by

F. J. Hooven

Ford Motor Co.

NOISE and vibration in unitized construction has to be taken care of by specific design for isolation and minimum coupling to noise sources. Conventional techniques used on body-frame cars are unsatisfactory. This is the lesson learned at Ford in working with its three unitized cars — the Lincoln, Thunderbird, and Falcon.

The unitized vehicle lacks the body mounts, which are a very effective filter against noise and vibration frequencies between the body and both the road and mechanical components. The frame functions as a separate anvil against the higher frequencies from both sources, and it is a difficult problem in the unitized cars to insert filtering means of equal effectiveness without having a similar mass to use for the purpose. Therefore, the designer must provide separate filtration and isolation means to control each source of noise and vibration.

Suspension as noise source

Front suspension transmitted road noises are found to be highly variable with tire design and compounding. High frequency sounds are both generated and transmitted through static friction in pivots and ball joints, and considerable improvement can be had by using rubberbacked pivot bearings, through the use of such plastic materials as teflon and polyethylene, which have low static friction characteristics, and by improved lubricants, which have a similar effect on metal joints.

Rear suspension noise problems differ radically from those of the front suspension. With the common solid-axle rear suspension, the greater unsprung weight constitutes a much more effective anvil against noise frequencies from the road, while acceleration moments are substantially absent in the noise range.

Axle gear noise

Axle gear noise and engine and propeller shaft vibrations are transmitted through the rear springs as well as through the propeller shaft. The isola-

"THE ENGINEEER'S job is to reduce noise and vibration to the point where it is subjectively acceptable, not to render them imperceptible," says the author.

"In a practical way this means that the sound of the vehicle must be low enough to permit intelligible conversation in normal tones under most operating conditions, and the sound of the clock ticking may be heard at 60 mph.

"The intelligibility of conversation resides in some very low level sounds with frequencies over 1000 cps, so that intelligibility of speech is affected more by the reduction of the higher frequency noises as long as they are not completely masked by the low frequencies."

"It also helps to have a clock with a good loud tick."

Noise and Vibration in Unitized Cars

. . . continued

tion of these sources is the most severe rear suspension problem in the unitized vehicle. Axle noise is almost entirely gear noise consisting of the gear tooth frequencies and their harmonics. Gear tooth pressure bearing loads cause deflection in the axle carrier structure itself, with resultant linear accelerations of the axle mass. Gear tooth inaccuracies result in torsional accelerations about both the wheel axis and the propeller shaft axis, of which the most troublesome is that about the wheel axis because of the lower moment of inertia in that direction. These frequencies are bound to appear because no axle has the weight or strength to take present-day tooth loads without deflection.

Axle gear noise is isolated from the vehicle structure in the Lincoln in four ways, and in two ways with the Falcon and Comet. All have large diameter rubber bushings in the spring eyes, and rubber interleaf liners in the springs (Fig. 1). The Lincoln has, in addition, a rubber pad between the axle and the spring, and a rubber isolated propeller shaft.

Engine and propeller shaft vibrations

Engine and propeller shaft vibrations reach the car structure mainly through the engine mounts, and to some degree through the rear suspension. The offending frequencies are in the 60–110-cps range — the same order of magnitude as the cavity resonances of the body. The Falcon has a vibration of about 60 cps which is a fundamental bending mode of the engine-transmission assembly. This is excited at various car speeds by various sources, including the propeller shaft first and second order, engine main bearing inertia loads first order, engine firing first, third, and sixth order. With the 3.10 axle, these periods occur at about 78 mph for the first order, 39 for the second, 26 for the third, and 13 for the sixth. Since the vibrations take place in both horizontal and vertical planes at somewhat different frequencies, and the various exciting sources favor different planes of vibration, these periods do not fall precisely on the sub-multiples of the fundamental speed.

Efforts have been devoted to reducing these vibrations by increasing the rigidity of the assembly to raise the first-order period beyond the normal running speed, or by introducing some kind of damping. The most troublesome vertical mode is taken care of on the Lincoln by using a tuned mass damper consisting of a spring-tuned mass in a can of oil, as shown in cross-section in Fig. 2. Experiments with tuned dampers without oil on the Falcon brought inconsistent results due to the sharpness of tuning of the relatively undamped oscillating mass.

Engine bending oscillations

Engine bending oscillations are ordinarily most troublesome in the vertical plane because of the necessary alignment of the rear mount, and the greater responsiveness of nearby floor pans to that mode of vibration. Such oscillations normally have a node very near the flywheel housing, and a useful reduction of noise and vibration can be had by locating the engine mount nearer this node. A typical dimensional effect is represented by the difference between the Falcon rear mount and the Comet mount, which has been moved forward and attached to a separate cross-member, as shown in Fig 3. The Falcon mount is acceptable with the lighter and cheaper construction, but the more expensive design was required for the Comet because of its longer driveshaft.

The excitation of engine-bending oscillations is much more serious in the in-line engine than in the 90-deg, V engine. The 6-cyl engine is a bad offender since balance is achieved by equalizing rather widely spread opposing forces within the structure of the engine itself. The alternating configuration of primary reciprocating inertia loads are in complete external balance, yet subject the engine structure to a very large lengthwise bending moment, which alternates as a first-order crankshaft frequency. These forces cannot be balanced out by counterweights, inasmuch as they are reciprocating, not rotating, vectors.

The 90-deg, V-8 engine, on the other hand, has relatively mild first order excitation of engine bending modes due to engine reciprocating inertia,

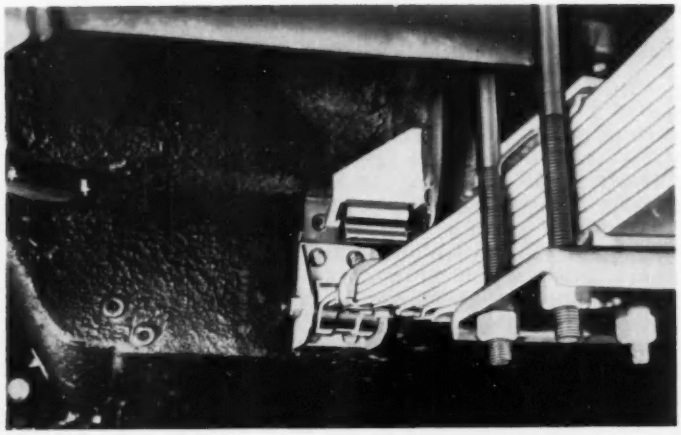


Fig. 1 — To isolate gear noise in its unitized cars, Ford uses large diameter rubber bushings in the spring eyes, and rubber interleaf liners in the springs.

and all primary inertia forces can be balanced out with counterweights.

Watch the accessories

Engine accessories are found to be potent exciters of engine bending modes, both because of their higher operating speeds and because of their distance from the vibration node. Generators and fans have to be balanced within close limits, and generator brackets must be rigid enough to keep the natural frequency above the first-order operating speed. Other small auxiliary devices that may be mounted to the engine by attachments that have modes of vibration within the operating range will become perceptible within the unitized vehicle unless specific provisions are made to prevent and isolate such vibrations.

To Order Paper No. 143B . . .
from which material for this article was drawn, see p. 6.

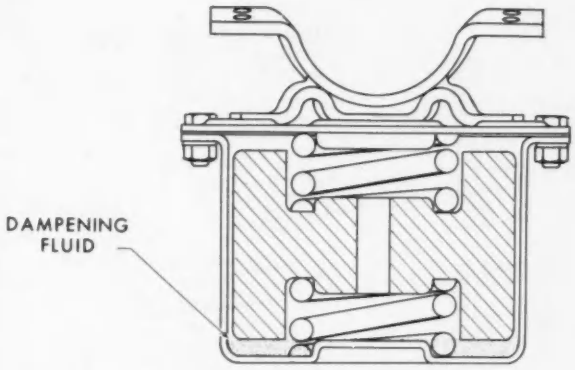
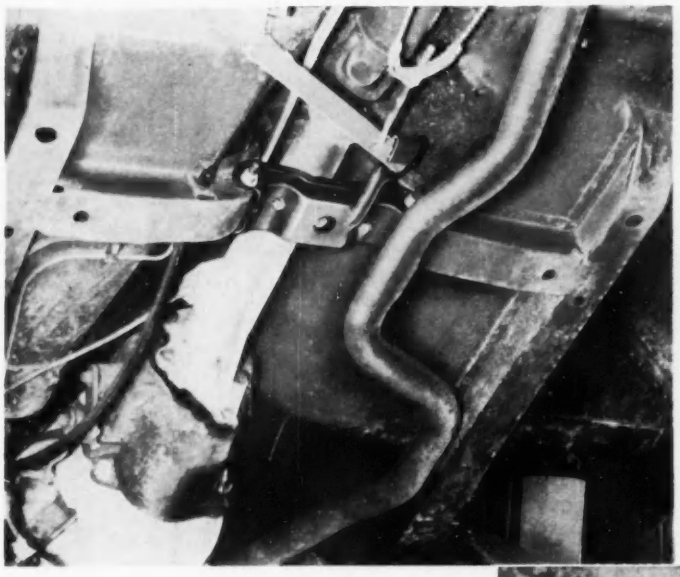


Fig 2 — Damping out the most troublesome vertical mode of engine and propeller shaft vibrations in the Lincoln is accomplished by a damper consisting of a spring-tuned mass in a can of oil.



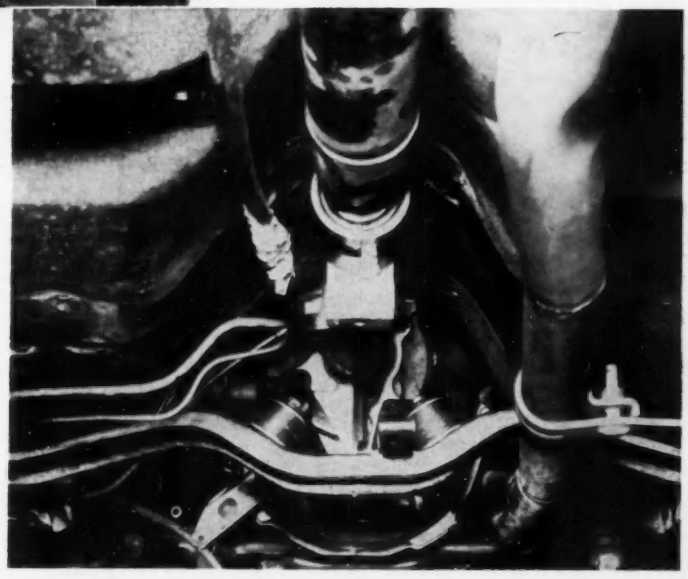


Fig. 3 — Rear mount of Falcon engine is shown at the top. Comet rear mount, shown at right, has been moved forward and attached to a separate cross-member because of its longer driveshaft.

SAE AERO-SPACE APPLIED THERMODYNAMICS MANUAL

Part C TEST INSTRUMENTATION AND MEASUREMENT (CONT'D.)

Table 2 (Sheet 1 of 2)

CHARACTERISTICS OF COMMON THERMOCOUPLE MATERIALS

Thermocouple Materials with ISA Designation		Copper-Constantan (T)	Iron-Constantan (J,Y)	Chromel-Alumel (K)	Platinum -10%PT.RH (S)	Platinum 13%PT.RH (R)
Positive Metal		100% CU	100% FE	90% NI 10% CR	90% PT 10% RH	87% PT 13% RH
		55% CU 45% NI	55% CU 45% NI 1% FE-MN	94.5% NI 2.5% MN 2% AL 1% SI	100% PT	100% PT
				0	0 to 2800°F	0 to 2800°F

SEC 3 REV.

FIGURE 3D-12 VANED OUTLETS

able that high velocity of discharge will spread the jets
s is not known.

Jets

Projected Jets - Experimental data on the path of a projected jet of heated or cooled air has been correlated. The trajectory of a jet of chilled air will appear of a stream of water projected horizontally through air by the same buoyancy (gravitational) forces.

SAE AERO-SPACE APPLIED THERMODYNAMICS MANUAL

Part B CHARACTERISTICS OF EQUIPMENT COMPONENTS (CONT'D)

SEC 3 PAGE B-38 REV.

(a) Sliding Vane Compressor

(b) Lobe Compr...

Discharge area

(c) Axial Flow Helical Lobe Compressor

FIGURE 3H-31 - ROT... Compressors (Figu... ...gma by in...

SEC 1 PAGE C-21 REV

...TRANSFER (CONT'D)

...ength Fins Welded Together Near One End (Figure 1C-20)

SEC 3 PAGE B-6 REV

...PPLIED THERMODYNAMICS MANUAL

...t B REFRIGERATION SYSTEM DESIGN (CONT'D.)

Ram Compression (work input)

Heat Rejection to Coolant

Heat Input from Cabin

Expansion (shaft work output)

For System A

Entropy

Cooling Fluid In

B.E.

Pump

Work

Turbine

Cooling Fluid Out

Cabin

...DENSITY A - RAM SUPPLY

AERO-SPACE APPLIED THERMODYNAMICS MANUAL

SAE AERO-SPACE APPLIED THERMODYNAMICS MANUAL

...PICAL CHECK VALVES

FIGURE 3H-99 WEIGHTS OF TYPICAL ELECTRIC MOTOR-DRIVEN BUTTERFLY SHUTOFF VALVES

WEIGHT, LB.

STEEL

ALUMINUM

INSIDE DIAMETER, IN.

SAE AERO-SPACE APPLIED THERMODYNAMICS MANUAL

Part E CHARACTERISTICS OF WORKING FLUIDS (CONT'D)

SEC 2 PAGE E-20 REV.

SAE AERO-SPACE APPLIED THERMODYNAMICS MANUAL

Part B THERMODYNAMICS AND ... FLOW (CONT'D)

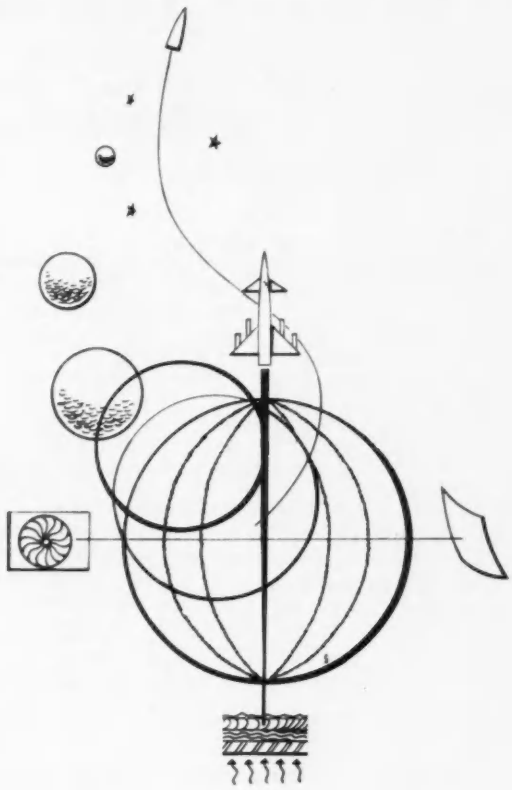
...ure Vs. Distance Along Nozzle

SEC 1 PAGE A-2 REV.

...ID

ASPECT RATIO - a/b

SAE Sires New Aero-Space Applied Thermodynamics Manual



Comprehensive 1000-page manual is one-stop reference for designing fluid thermodynamic airborne and space vehicle systems. Basic data, however, apply to thermodynamic problems in aero-space and ground vehicle industries.

FIVE BASIC engineering functions have been combined for the first time in the new SAE Aero-Space Applied Thermodynamics Manual.

Its 1000-odd pages of basic information supply:

- The solution of most practical air-conditioning and power-pneumatics problems, as well as of some hydraulics problems.
- A complete standardization of symbols and nomenclature.
- Accepted industry methods of approach to typical design problems.
- A very complete source of thermodynamic properties of materials available under one cover.
- Information that can be kept always up-to-date. The manual is in loose leaf form and will be regularly supplemented by the latest engineering thermodynamic data and techniques.

The manual represents five years of concentrated work by SAE's Committee A-9 (Aero-Space Environmental Control Systems). The Committee's work in development and completion of this manual was preceded by four separate projects in related fields. As a result, the manual reflects the best engineering knowledge in the United States on solution of thermodynamic aero-space problems.

Is it a textbook?

This Applied Thermodynamics Manual picks up where typical text-book learning finishes. It carries forward past the text-book stage in three ways.

FIRST, in a section on engineering fundamentals, it brings together the directly usable results of both theory and practice on:

- Compressible and incompressible flow.
- Heat transfer.
- Mass transfer.
- Air-and-water mixtures.

SECOND, in a thermo-physical properties section, it provides a very complete and authoritative single source of information on the gases, liquids, and solids commonly used in aero-space systems. It both tabulates and charts this information.

THIRD, in its section on application engineering, it details methods of designing complete heating, re-

The Engineers Behind the Manual

SAE Committee A-9 "Aero-Space Environmental Control Systems"

(formerly "Aircraft Airconditioning Equipment") — January 1, 1960

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frigeration, and pressurization systems, as well as external ice protection systems. This section also includes analysis of individual components, test equipment, and aircraft penalty evaluation.

By using these three sections of this single volume, a junior or uninitiated engineer in the field when assigned to a new project can assemble all the theory, practice, and empirical data necessary for solution of a particular problem. For example, the performance of the air turbine for the air-conditioning system of the F104-B shows how the manual can be used for a simple specific problem. The radial inward flow turbine in the F104-A had been optimized for that plane's requirements. The question was "How well will it perform in the F104-B with a higher inlet pressure?"

By going to page H-56 of Section 3 of the Manual, the engineer computing the performance finds the necessary calculation steps and solves for the turbine performance for the various flight profiles.

The problem does not end here, of course, for the new performance figures of the turbine must be related to the new ducting, valves, and other components in the F104-B. However, air-cycle refrigeration system analysis is also spelled out in Section 3. Such factors as flow losses in ducts and heat transfer rates for specific geometry come from Section 1 while thermodynamic data on the working fluid is found in Section 2.

Order out of confusion

One of the simplest ideas — yet the hardest to achieve — is to get engineers to talk the same language. This ranges from calling a part by one name to the reporting of results on a complex system. The manual has met this challenge on four major fronts:

(a) symbolization of engineering terms; (b) units of measure; (c) nomenclature of parts and processes; and (d) approaches to and performance-reporting of design procedures.

Through continued use of the manual, there will be an extra saving of engineering time within and between companies because of a growing ease of communications and a simplification of calculations. Some examples of this unified industry approach are:

- Common units are used for terms such as thermal conductivity, specific heat, and heat of vaporization, while presently different units are used from reference to reference.
- Clarifies the selection of appropriate standard atmosphere data.
- Standardization of symbols used throughout the manual is based upon actual present engineering practice.
- Controversial definitions are pinned down, like counterflow heat exchanger versus multi-pass cross-flow heat exchanger, or proportional control valve versus modulated control valve.
- Common ground rules are established for measurements or reporting of data that range from evaluating the aircraft penalty incurred with an air-conditioning system to the method of calculating flow loss through a valve.

How to Get and Use the Aero-Space Applied Thermodynamics Manual

COPIES of the manual can be obtained from SAE for $25 each (plus $2 service charge outside the U. S.) by filling out and sending in the order blank on page 6.

Each copy of the manual is registered, so fill in the mailing address where you want to be notified of future revisions. Revision kits are expected to be available at nominal cost every three months to a year. They will contain new data and extensions of existing data.

SAE Committee A-9 has designed the manual to be a constantly up-to-date complete information source on aero-space thermodynamic problems. The manual now issued is the first and basic publication. It should be considered and used as a permanent reference source.

Upgrading and expanding data

A double-barreled treatment of emperical data is a major strength of the manual. A comprehensive sorting has brought the most authoritative data together in Section 2 while a revision kit concept promises to keep manual users supplied with the last information.

Each of the thermo-physical charts for gases, liquids, and solids is constructed to give a full and reliable range of properties, whether the basic information was obtained from one or many sources. As information on any of the materials expands, such as to higher temperatures, the charts will be corrected and re-issued. In this way, the idea of a single master reference volume is kept intact. Also, emperical data on new materials will be added as their use becomes significant to aero-space vehicles.

Basic theory and practice will also undergo constant revisions. For instance, the present 32 pages on radiation heat transfer will be supplemented with characteristics of radiation between the earth, sun, moon, and satellite as soon as it becomes available.

The reliability of the data and procedures outlined in the manual is enhanced by the hundreds of references listed with the different sections and parts. In this way the user does not have to take on faith the basic source of data. In fact, it may well happen that an engineer finds his whole fundamental reference library and more are listed as sources in the manual. Also, as the members of Committee A-9 already know, information from valuable but hard-to-get sources is already in the manual.

Outline of Contents of the Manual

▶

Outline of Contents of

SAE Aero-Space Applied Thermodynamics Manual*

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Basic Fluid Mechanics
Specific Loss Data

THERMODYNAMICS AND COMPRESSIBLE FLOW
First Law of Thermodynamics
Ideal or Perfect Gases as Working Fluids
The Second Law of Thermodynamics
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Thermodynamics of High Velocity Gas Flows

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PROPERTIES OF LIQUIDS

PROPERTIES OF SOLIDS

THERMODYNAMIC CHARACTERISTICS OF WORKING FLUIDS

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Skin Temperature Computational Methods
Cooling Loads Due to Radiation Through Transparent Areas
Heating and Cooling Loads Due to Internal Sources
Practical Considerations in the Determination of Overall Heating and Cooling Loads
Example Illustrating Skin Temperature Computation by Reference Enthalpy Method

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General Aircraft Air Conditioning Considerations
Brief Definitions of Available Heat Sinks
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Vapor Cycle Systems
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External Factors Affecting Heat Requirements
Airfoil Evaporative Anti-Icing
Running-Wet Anti-Icing
Electro-Thermo Cyclic De-Icing
Determination of Need for Ice Protection
Illustrative Examples

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Temperature Measurement
Fluid Flow Measurement
Measurement of Other Fundamental Quantities

CHARACTERISTICS OF EQUIPMENT COMPONENTS
Pumps
Fans
Compressors
Turbines and Air Motors
Jet Pumps
Valves
Heat Exchangers

AIRCRAFT PENALTY EVALUATION
Equivalent Drag Method
Breguet Range Equation Method
Sample Calculation

* Library of Congress Catalog Card Number 60-13450.

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John A. C. Warner Retires

as SAE Secretary and General Manager; will continue as advisory consultant

JOHN A. C. WARNER had completed 30 years as SAE secretary and general manager, when he retired from that post July 1, 1960. At the request of the Board of Directors, he will continue to serve the Society as an advisory consultant.

To date, John Warner has served SAE a total of 33 years. He first joined the Society staff in 1923 as assistant manager of the Research Department, then became its manager. A year or so later, he became manager of Sections and meetings. Then, in 1926, he went to Studebaker Corp. to serve four years as assistant research manager, before returning to SAE when he was elected to be secretary and general manager of the Society, beginning in July, 1930.

Speaking of Warner's appointment as advisory consultant, SAE President Harry E. Chesebrough says:

"SAE has benefited greatly during the 30 years John Warner has been secretary and general manager from his unusual ability to stimulate the interest of industry's outstanding engineers in SAE work; from his ability to bring to all members a vision of opportunity for service through cooperative SAE effort; and from his ability to guide and counsel with SAE-active engineers as each made his personal and individual contribution.

John's activities as advisory consultant provide an opportunity for the Society to benefit in the future as in the past from continued application of these unusual talents to SAE progress."

Joseph Gilbert Appointed
as SAE Secretary and General Manager

JOSEPH GILBERT became secretary and general manager of the Society of Automotive Engineers on July 1, 1960, succeeding John A. C. Warner. He is the third to hold this post in the Society's 55-year history. Coker F. Clarkson, SAE's first secretary and general manager, served from 1910 to 1930; John A. C. Warner from 1930 to 1960. Gilbert has been assistant general manager since 1957, and a member of the Society's headquarters staff for 14 years.

As assistant general manager, Gilbert was in charge of the operations of the headquarters staff. During this period also, he has assisted the officers and Board of Directors in the carrying out of many administrative policies, and has made frequent visits to Section meetings and to Section governing boards.

Gilbert played an important role in the Planning for Progress work which led to the Society's present organizational structure. As secretary of the Planning for Progress Committee, he was a centerpoint in the development. On the one hand, he was responsible for servicing the Committee and its studies. On the other, he was responsible for effecting the realignment of staff and operational services required to service the expanded opportunities of the new structure.

President Harry E. Chesebrough, at the time of Gilbert's election at the June 10 Board of Directors meeting, commented:

"Gilbert has combined initiative effectively with wisdom in his direction of the headquarters staff through a complex period of changing requirements."

Gilbert started his SAE career in the Publication Division. There his work put him in contact with every technical and administrative phase of the Society's work. He was part of a publications staff whose function it is to find out what's going on — and to interpret for SAE Journal readers what it means.

Before moving further ahead, he had become assistant manager of the Publication Division — and managing editor of SAE Journal.

Then he was advanced to become manager of the Technical Committee Division, serving also as secretary of the SAE Technical Board. Briefly, he was responsible for the Activity Division . . . which serves and works with the Activity Committees, now agencies of the Engineering Activity Board. For several years, he was staff representative for four Activity Committees.

For more than four years, Gilbert also has headed the staff activity which assists the Finance Committee to gain financial recognition for the SAE Cooperative Engineering Program.

Of Gilbert's work as assistant general manager, former secretary and general manager John Warner said last year: "SAE has profited increasingly as we have accelerated and broadened the opportunities for Gilbert's talents to be applied."

Before coming to SAE in 1946, Gilbert was an industrial engineering officer in the Air Force during World War II, with responsibilities in development of plant and manufacturing facilities for production of aircraft, engines, and components.

He has a Master of Science degree in Industrial Engineering from Columbia University; a Bachelor's degree in Engineering from the College of the City of New York. Gilbert will be 40 years old next December.

He is married; has a 14-year old son, and a 10-year old daughter.

Attendance tops 2000 for a new all-time record at

1960 SUMMER MEETING —*in Chicago*

WHAT'S NEW dominated technical - information exchanges at the 1960 SAE Summer Meeting in Chicago, June 5–10. Both breadth and depth of treatments were increased, with science-engineering topics continuing on the upbeat. Fuel cells and plastic-clad metals, for example, were on the program the day the meeting started, while plasma technology and the latest in combustion research and surface finishing were among the later discussions.

The surface finish session on Wednesday afternoon saw engineers from Great Britain and Canada joined in interests with a large group of United States technicians. Before and after the technical sessions, meetings were held of the surface finish group of the American - British - Canadian Standards Conference, with official delegates participating from each of the three nations. (See picture at top of opposite page.)

The total number of technical sessions (32) and the average attendance at each surpassed that of any previous Summer Meeting . . . as did the total number of papers presented (78). Total attendance at meeting — where social events were deemphasized — ran over the 2000 mark, considerably ahead of last year's Atlantic City gathering.

A special program of unusual interest was set up for the ladies on every day of the meeting. The ladies' events included bridge parties and a full day's tour of Chicago's famous Merchandise Mart. Joint social events during the week were the "Welcome Party" staged Sunday evening and the "Midweek Mixer" on Wednesday evening. The later event was built around a "Roaring 20s" theme.

"What's New" Areas

Technical areas in which the "what's new" theme was emphasized included the following: heat treatment, fuel cells, tracers in machining; plastic-clad metals, plasma technology, gas turbines for ground vehicles, markets for automotive products, surface finish, and car-highway relationships for the future.

Committee meetings were numerous, as usual, in both technical committee and the administrative areas. Headed by the Board of Directors meeting on Friday, June 10, the list of meetings included every one of the Society's major administrative groups. The SAE Technical Board held its first meeting during a Summer Meeting in many years. The Engineering Activity Board and the Sections Board — the two other bodies which administer wide areas of the Society's member activities — also met during the week. Other major administrative committees to meet were the Finance Committee — which reviewed some preliminary budget estimates for the next fiscal year . . . and the Publication Committee, which moved one step nearer to completion of its study of revisions in the SAE publications setup needed to meet currently fast-expanding member needs.

Most important action taken at the Board of Directors meeting was election of Joseph Gilbert to be SAE Secretary and General Manager, after appointment as advisory consultant of John A. C. Warner. (See pg. 92–93.) Following its meeting, the Directors held a luncheon in honor of John Warner to celebrate his completion of 30 years as the Society's Secretary and General Manager. (See picture on p. 102)

A STUDENT ACTIVITY COMMITTEE meeting was held under the chairmanship of Committee Vice-Chairman K. W. Gordon. The group approved issuance of a new booklet titled "Ideas for Student Branch Development." Gordon (third from left) is shown discussing the booklet with committee members Ernest Starkman, A. D. Gilchrist, Wallace F. Denny, F. B. Esty, and Sections Board Chairman W. F. Ford.

AMERICAN-BRITISH-CANADIAN SURFACE FINISH CONFERENCE — Close accord on the adoption of uniformity in the surface finish standards of three nations was achieved in Chicago at the June 8-9 joint meetings of ASA Sectional Committee B46, the SAE Surface Finish Committee, and ABC representatives from America, Britain and Canada. The standards involved cover uniform measurement of surface finish waviness and lay.

Thirty-two delegates attended the joint meetings which were scheduled before and after the SAE Surface Finish session Wednesday afternoon.

ABC Delegates Seek Accord On Surface Finish Standards

LEADING THE BRITISH DELEGATION was Dr. Cecil Timms (extreme right) shown here with British delegates M. P. Rubert, R. E. Reason, and Mrs. Doris Cowley of the British Standards Institution.

CANADIAN AND AMERICAN DELEGATIONS were headed by H. B. Elliott (center) and Dr. C. R. Lewis (right), who appear with Canadian delegate E. A. Sprenger. Dr. Lewis is also chairman of the SAE Surface Finish Committee.

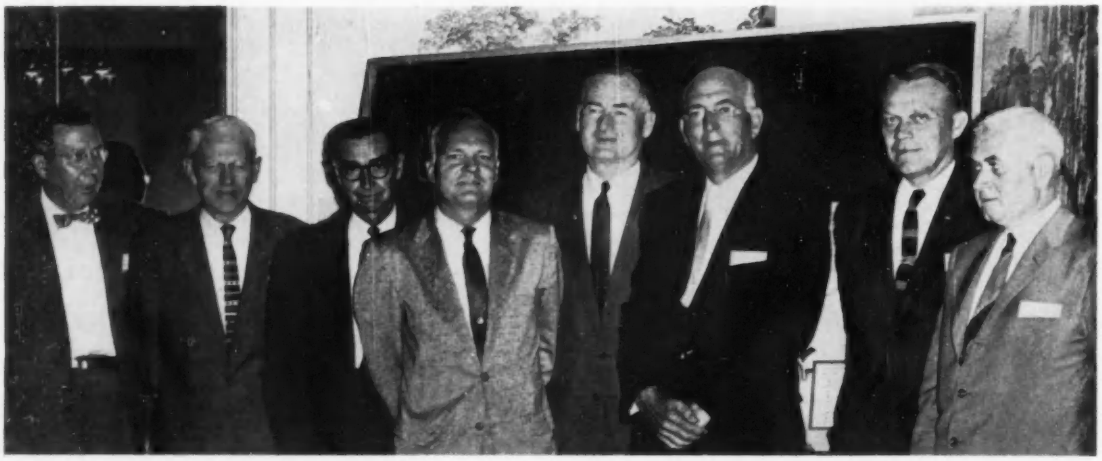
NEW CHAIRMAN of ASA Surface Finish Sectional Committee (B46) is Fred W. Witzke (right) shown with Arnold W. Young, who pinch-hit for R. P. Trowbridge as secretary at the joint sessions.

RELEASE OF THE SAE AERO-SPACE THERMODYNAMICS MANUAL developed by Committee A-9 on Aero-Space Environmental Control Systems was announced by Carl Sadler (facing forward), chairman of the Board's Aero-Space Council. (See p. 86 for full story.)

At the Technical Board Luncheon . . .

A NUMBERING SYSTEM to identify all ground vehicle technical committee reports was approved at the Board meeting. Proposed by Technical Board Publication Policy Committee Chairman Harold Nutt (facing camera near mirror), the system will be reviewed by ground vehicle councils and technical committees.

CONSOLIDATION OF FASTENER ACTIVITIES presently handled by the Screw Threads Committee and the Parts and Fittings Committee, resulted in the formation of the SAE Fasteners Committee. General Standards Council Chairman E. C. Brown, who reported this action to the Board, is shown at extreme left.



THE SAE TECHNICAL BOARD is moving ahead on plans to feature a major display on the achievements and industry services of some 350 SAE technical committees operating under the Councils of the Board. The display will be a feature of the Science Pavilion at the SAE International Congress and Exposition of Automotive Engineering to be held in Detroit next January. Gathered around Technical Board Chairman A. A. Kucher (third from right) after a meeting held at Summer Meeting are (from left) Muir Frey, Dr. Arthur Nutt, E. C. Brown, J. H. Dolan, G. E. Burks, Dr. Kucher, R. R. Burkhalter, and F. L. LaQue, who is spear-heading the display project.

BREAKTHROUGHS IN THE '60s is the theme of the SAE International Congress and Exposition of Automotive Engineering to be held in Detroit's Cobo Hall next January. This was announced by SAE President Harry Chesebrough (at head of table) at a press conference during Summer Meeting in Chicago.

SAE International Automotive Engineering Congress Announced At Chesebrough Press Conference

THE SAE INTERNATIONAL AUTOMOTIVE ENGINEERING CONGRESS will be the 1961 SAE Annual Meeting, it was announced by SAE President Harry E. Chesebrough.

This International Congress, Chesebrough told reporters at a press conference held during Summer Meeting, "will bring together in one place and at one time the key automotive engineers from the entire world to exchange the latest in engineering and scientific knowledge."

Theme for the Congress will be "Breakthroughs in the '60s." To be held in Detroit's new Cobo Hall, the Congress is expected to draw more engineers than ever before to its 60 technical sessions where the significance of recent developments will be projected into the future. The Congress will also house SAE's largest Engineering Display as well as a non-commercial display, the Science Pavilion, which will feature the X-15 and new wheel-less vehicles.

Harry Barr, chairman of SAE's Engineering Activity Board, Robert Johnson, a past SAE Director, and Ralph Isbrandt, chairman of the Exposition Advisory Committee, supplemented President Chesebrough's talk to reporters. Barr, who is Chevrolet's chief engineer, announced that over 150 papers, tailored to the interests and needs of today's engineer, will be presented at technical sessions. Two sessions, described by Robert Johnson, assistant to the general manager of Wright Aeronautical Division, as special project MOONBEAM, will feature papers on the design of an imaginary space vehicle which in 1970 is expected to go to the moon and back in scheduled service.

In pointing out the magnitude of Cobo Hall facilities, Isbrandt, director of automotive engineering and research, American Motors Corp., estimated that over 500 displays will fill the 200,000 sq ft Exposition area.

In closing, President Chesebrough observed that in planning the theme and technical content of the Congress, not much time was wasted looking back. Instead, attention was keyed to the future.

SUPPLEMENTING President Chesebrough's talk to reporters were (from left to right) Robert Johnson, past SAE Director, Ralph Isbrandt, chairman of the Exposition Advisory Committee, President Chesebrough, and Harry Barr, chairman of SAE's Engineering Activity Committee.

1960 SAE Summer Meeting included:

A Polyvinyl Alcohol Solution as a Quenchant for the Hardening of Steel, **P. E. Cary, E. O. Magnus, and A. S. Jameson,** International Harvester Co. **(178A)**

New Nitriding Process for Increased Wear and Fatigue Resistance, **G. S. Bidigare,** Commercial Steel Treating Corp., and **J. H. Shoemaker,** Kolene Corp. **(178B)**

Engineering Convection in Heat Treat Furnaces, **J. Huebler,** Surface Combustion Div., Midland Ross Corp. **(178C)**

Fuels Cells: Introduction, **L. D. McGraw,** Batelle Memorial Institute **(179A)**

The U.S. Army Research and Development Program in Fuel Cells, **Sidney Magram and B. R. Stein,** Chemistry & Materials Branch, Army Research Office **(179B)**

A Nitrosyl Chloride Solar Regenerative Fuel Cell System, **E. Findl, W. B. Lee, J. D. Margerum, and W. E. McKee,** Sundstrand Turbo Div., Sundstrand Corp. **(179C)**

The Marvibond Process — Seven Years' Experience, **P. E. Roggi and C. E. Kiernan,** Naugatuck Chemical Div., U. S. Rubber Co. **(180A)**

Production and Application of Vinyl-Coated Steel, **G. H. Rendel,** U. S. Steel Corp. **(180B)**

A New Approach to Vinyl Films on Steel, **W. G. Cryderman,** Kaybar, Inc. **(180C)**

Fusion Bond Coating — A New Technique for Plastic Cladding Metal, **W. R. Pascoe,** Polymer Corp. **(180D)**

Radioisotopes Broaden the Approach to Machining Studies, **Marko Paliobagis and E. J. Krabacher,** Cincinnati Milling Machine Co. **(181A)**.

Design Considerations for the Radio Chemical Laboratory in Industry, **L. C. Schwendiman,** General Electric Co. **(181B)**

The Applications of Radioisotopes in Machining Operations, **J. H. Tolan,** Nuclear Branch, Lockheed Aircraft Corp., Georgia Div. **(181C)**

Value Engineering — Key to Productivity and Profitability, **J. F. Prendergast,** General Electric Co. **(182A)**

Noise Quieting Principles for Rotary Type Power Lawn Mowers, **W. C. Sperry,** Armour Research Foundation **(183A)**

Vibration and Noise Control of Outboard Motors and Other Products, **J. W. Mohr,** Outboard Marine Corp. **(183B)**

Technological Advances in Hydraulic Brakes for Motor Trucks, **John Thomas,** Motor Truck Div., International Harvester Co. **(184A)**

Air Brakes Yesterday — Today, and Tomorrow, **R. B. Palmer,** Ford Motor Co. **(184B)**

The European Approach to Braking Standards, **C. W. Jackman,** Chevrolet Motor Div., General Motors Corp. **(184C)**

Ablation Cooling of Missiles and Satellites, **E. R. G. Eckert,** University of Minnesota **(185A)**

Plasma Propulsion, **S. W. Kash,** Missiles & Space Div., Lockheed Aircraft Corp. **(185B)**

Theoretical Prediction of the Effect of Traction on Cornering Force, **Walter Bergman,** Ford Motor Co., **(186A)**

Experimental Determination of the Effect of Traction on Cornering Force, **C. A. Freeman,** Ford Motor Co. **(186B)**

Tread Wear Operating Variables and Index Determination, **J. L. Ginn, R. F. Miller, and R. L. Marlowe,** B. F. Goodrich Co. **(186C)**

Mechanics of Tire Squeal, **R. F. Miller,** B. F. Goodrich Co. and **J. G. Slaby,** National Aeronautic & Space Administration **(186D)**

An Advanced Automotive Gas Turbine Engine Concept, **I. M. Swatman and D. A. Malohn,** Turbo Machine Dept., Ford Motor Co. **(187A)**

The Film Vaporization Combustor, **A. W. Hussmann,** Pennsylvania State University, and **G. W. Maybach,** Maybach Motorenbau **(187B)**

The New Awareness on Management Information and Control Systems, **W. E. Alberts,** United Air Lines, Inc. **(not available)**

How To Improve Plant Layouts, **N. L. Schmeichel,** Sterling National Industries **(189A)**

The Economics of Revising Plant Layouts, **John McIntosh,** Ernst and Ernst **(189B)**

Fuel Injection and Positive Ignition — A Basis for Improved Efficiency and Economy, **C. W. Davis, E. M. Barber, and Edward Mitchell,** Texaco Research Center **(190A)**

Development of a Cylinder Water Seal to Prevent Diesel Engine Crankcase Cavitation — Erosion, **A. B. Neild, Jr.,** U. S. Naval Engineering Experiment Station **(191A)**

Laboratory and Field Findings Pertaining to Axle Lubricants, **W. A. Johnson,** Rockwell-Standard Corp. **(192A)**

A Report on Transmission Lubricant Requirements, **R. E. Fletcher,** Dana Corp. **(192B)**

Comparison of Axle and Transmission Lubricant Requirements, **R. K. Nelson and L. J. Valentine,** Eaton Mfg. Co. **(192C)**

The Practicality of a Common Transmission and Axle Lubricant, **S. R. Calish,** California Research Corp. **(192D)**

How Textiles Increase Your Horsepower, **R. T. Chatham,** Chatham Manufacturing Co. **(193A)**

Friction of Transmission Clutch Materials As Affected by Fluids, Additives and Oxidation, **M. L. Haviland and J. J. Rodgers,** Research Labs., General Motors Corp. **(194A)**

A Radioactive Tracer Study of Lubricating Oil Consumption, **E. S. Starkman,** University of California **(194B)**

Metallic Tracer Method for Determining Lubricant in Engine Exhaust, **J. C. Neerman, F. R. Bryan, and J. E. Hinsch,** Scientific Lab., Ford Motor Co. **(194C)**

Effects of the Support System and Stylus Radius on Roughness Measurement, **F. W. Kabat and C. H. Good,** Micrometrical Mfg. Co. **(195A)**

Roundness and Its Ramifications, **E. E. Lindberg,** Research Labs., General Motors Corp. **(195B)**

Measurement of Surface Waviness of Rolling-Element Bearing Parts, **O. G. Gustafsson and U. A. Rimrott,** SKF Industries, Inc. **(195C)**

Measurement, Evaluation and Specification of Surface Finish of Tubing, **W. C. Harmon,** Republic Steel Corp. **(195D)**

Computer Simulation of Automotive Fuel Economy and Acceleration, **R. K. Louden and I. K. Lukey,** Buick Motor Div., General Motors Corp. **(196A)**

Computer Predicts Car Acceleration, **H. L. Setz,** Ford Motor Co. **(196B)**

Problems Associated with Windshield Wiping, **J. S. Clarke and R. R. Lumley,** Joseph Lucas, Ltd. **(197A)**

International's Model 817 High Output Diesel Engine, **D. J. Bundy and E. H. Stromberg,** Construction Equipment Engineering Dept., International Harvester Co. **(198A)**

Should the Engine or the Engineer Get the Last 5 Horsepower?, **M. F. Sterner,** Holley Carburetor Co. **(199A)**

Forecasting Specific Fuel Economy, **P. M. Clayton,** Ford Motor Co. **(199B)**

From 4 Plies to a Single Ply In Steel-Cord Casing Tires, **M. P. Baumont,** Manufacture des Pneumatiques, Michelin **(200A)**

Cord Fatigue in Fleet Tested Tires, **W. G. Klein, M. M. Platt, and W. J. Hamburger,** Fabric Research Laboratories, Inc. **(200B)**

Tire Branding and Inventory Control, **R. W. Kupp,** Consolidated Freightways, Inc. **(200C)**

A Consideration of the Deposit Ignition Mechanism, **F. W. Bowditch and T. C. Yu,** Research Labs., General Motors Corp. **(201A)**

Concurrent Pyralytic and Oxidative Reaction Mechanism in Precombustion of Hydrocarbons, **C. E. Welling, G. C. Hall, and J. S. Stepanski,** Ford Motor Co. **(201B)**

Unsteady Heat Transfer in Engines, **V. D. Overbye,** University of Wisconsin, **J. S. Bennethum,** Research Labs., General Motors Corp., and **O. A. Uyehara and P. S. Myers,** University of Wisconsin **(201C)**

End-Gas Temperature Measurements by a Two-Wavelength Infrared Radiation Method, **W. G. Agnew,** Research Labs., General Motors Corp. **(201D)**

The Measurement of Unburned-Gas Temperatures in an Engine by an Infrared Radiation Pyrometer, **M. B. Burrows,** NASE Lewis Lab., **S. Shimizu,** Nagoya University, and **O. A. Uyehara,** and **P. S. Myers,** University of Wisconsin **(201E)**

End-Gas Temperature Pressure Histories and Their Relation to Knock, **M. E. Gluckstein, Cleveland Walcutt, Jr., and R. R. Acles,** Ethyl Corp. **(201F)**

Recent Developments in Cam Design, **J. H. Nourse,** Engineering Consultant, **R. C. Dennis,** Atomic Power Development Assoc., and **W. M. Wood,** Associated Spring Corp. **(202A)**

Cures for Powerplant Bending Noise Problems, **R. H. Bollinger, and J. H. Ruhl,** Ford Motor Co. **(203A)**

Engine Mountings — Automotive Workhorses, **Gerald Klaasen,** Chrysler Corp. **(203B)**

How to Keep the Small Fleet Sparkling, **R. L. Fiske,** General Industries Div., Oakite Products, Inc. **(204A)**

Are You "Married" to the Right Vehicle Washer?, **Monroe Lewis and Sidney Mindlin,** Jet Spray Auto Washer Corp. **(204B)**

Choosing Equipment for a Large Wash Rack Installation, **C. P. Ross and R. W. Burrill,** Ross & White Co. **(204C)**

Motions of Skidding Automobiles, **W. F. Milliken, Jr., and H. S. Radt, Jr.,** Cornell Aeronautical Lab., Inc. **(205A)**

The Influence of Tires and Their Variables on Passenger Car Skidding, **A. H. Easton,** University of Wisconsin **(205B)**

The Influence of Road Surfaces and Their Variables on Passenger Car Skidding, **O. K. Normann,** U. S. Bureau of Public Roads **(205C)**

Are Octane Numbers and Hydrocarbon Type Enough?, **F. D. Buerstetta and I. A. Caputo,** Ethyl Corp., and **E. S. Corner, T. M. Korn, and E. C. Younghouse,** Esso Research & Engineering Co. **(206A)**

Tetramethyl Lead, An Antiknock for Better Road Performance, **R. H. Perry, Jr., C. J. Diperna, and D. P. Health,** Socony Mobil Oil Co., Inc. **(207A)**

The Antiknock Behavior of the Alkyl Lead Compounds, **H. E. Hesselberg and J. R. Howard,** Ethyl Corp. **(207B)**

Automotive Sprag Clutches — Design and Application, **E. A. Ferris,** Spring Div., Borg-Warner Corp. **(208A)**

Roller Clutch Design, **R. E. Sauzedde,** New Departure Div., General Motors Corp. **(208B)**.

Transmission Gear Design for Strength, **E. L. Jones,** Axle & Gear Functions Lab., Chrysler Corp. **(208C)**

Manufacturing Considerations Affecting Transmission Gear Design, **Alex Hardy,** Detroit Transmission Div., General Motors Corp. **(208D)**

Gear Design for Noise Reduction, **W. D. Route,** Chevrolet Motor Div., General Motors Corp. **(208E)**

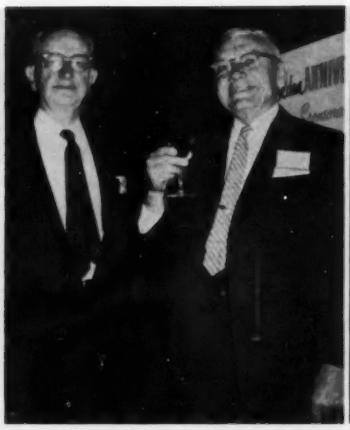
Utility of Tetramethyl Lead in Gasoline, **D. L. Pastell and W. E. Morris,** E. I. du Pont de Nemours & Co., Inc. **(207C)**

Tetramethyl Lead Reduces Low Speed Knock, **T. M. Korn,** Esso Research & Engineering Co., and **G. Moss,** Esso Research Ltd. **(207D)**

The Motor Vehicle Aspect of Traffic Safety, **C. W. Prisk,** U. S. Bureau of Public Roads **(209A)**

Papers are available through SAE Special Publications Dept. Prices: 50¢ a copy to members; 75¢ a copy to nonmembers.

CONFERRING WITH TOASTMASTER W. PAUL EDDY (center) are ISTC Program Chairman Robert Sergeson (left) and L. E. Webb. During the dinner, Eddy read a letter of commendation from Automobile Manufacturers Association President L. L. Colbert.



TOASTING THE NEXT 50 YEARS is M. W. Dalrymple, retiring chairman of Division 7—Carbon Steels. At left is Harry Knowlton, who has participated in ISTC work for many years.

ISTC CHAIRMAN JOHN GRAHAM welcomes SAE President Harry Chesebrough. Earlier this year, Chesebrough transmitted a congratulatory letter to the ISTC from the SAE Board of Directors.

SAE Iron and Steel Technical Committee Celebrates Golden Anniversary

RECOGNITION FOR LONGEST SERVICE among those at the dinner went to Hy Bornstein (extreme right) who is shown with (from left to right) Past ISTC Chairmen Joseph Gurski, E. H. Stilwill, and F. C. Young.

AISI REPRESENTATIVE Douglas Allan is greeted by Golden Anniversary Planning Committee Chairman L. E. Webb. At the dinner, Allan conveyed a letter of commendation to the ISTC from AISI President B. F. Fairless.

RENEWING FRIENDSHIPS are Dr. E. T. Rowland, R. C. Sackett, and J. F. Kilmer. Sackett came from Florida and out of 'retirement' to be at the dinner.

AT ISTC GOLDEN ANNIVERSARY BANQUET, nine past chairmen were present at the speakers table. In attendance were 100 other metallurgists. At the speakers table (from left, top) are: E. H. Stilwill, Joseph Gurski, Muir Frey, Douglas Allan, who represented the AISI, SAE President Chesebrough, W. Paul Eddy. (Bottom) Lloyd Webb, 1960 Chairman J. D. Graham, Dr. E. T. Rowland, A. H. Smith, Hy Bornstein, F. C. Young, and R. C. Sackett, retired SAE staff member who worked with the Committee for many years.

1959 HORNING MEMORIAL AWARD went to E. S. Starkman (left) and W. E. Sytz (second from left) for their paper, "Identification and Characterization of Rumble and Thud," which was presented at last year's Summer Meeting. Mrs. Elsie M. Horning presented medals at the ceremony which was presided over by A. G. Cattaneo, chairman of the 1959 Award Committee.

SAE PUBLICATION COMMITTEE discussed plans for expansion of SAE facilities for publication of full length papers. From left are Leonard Raymond, Carl Lindblom, V. G. Raviolo (ex-officio member as chairman of the Engineering Activity Board's Publication Advisory Committee), Chairman T. L. Swansen, and M. G. Beard.

ENGINEERING ACTIVITY BOARD'S PUBLICATION ADVISORY COMMITTEE met on Monday, June 6. At this session the group moved further toward improved techniques for development and procurement of better quality papers and other technical information. In the photograph from left are: Carl Sadler, Publication Committee Chairman T. L. Swansen (an ex-officio member of the EAB-PAC), F. Phillip Steiner, J. A. Bolt, and Chairman V. G. Raviolo.

IN-COMING CHICAGO SECTION OFFICERS and one past chairman are shown at the Welcome Party. From left is Treasurer W. H. Day, Vice Chairman P. J. Sperry, Secretary I. R. Dawson, and Past Chairman Orville Brouer.

. . . Welcome Party

AT SUNDAY NIGHT'S WELCOME PARTY, Chicago Section Reception Committee Chairman T. J. Jenkins and his wife were on hand to greet some 300 SAE members and guests. Throughout the rest of the week, Jenkins and a team of Chicago Section members keyed out-of-towners in on Summer Meeting events.

At the Summer Meeting . . .

Midweek Mixer . . .

APPROPRIATELY ATTIRED for the occasion are SAE Past-President Leonard Raymond and Mrs. Raymond who saw Mrs. Edward Muelhoefoer and Paul Oberreutter take first prize in the Charleston contest.

THE ROARING TWENTIES was the theme of the Midweek Mixer held Wednesday evening. Flanking James Greenlee, past chairman of the Chicago Section, are Mrs. Greenlee (left) and Mrs. David Peterson.

CHICAGO SECTION CHAIRMAN Edward Hendrickson (right) is shown at Mixer with his brother, Robert (who served as Chicago Section chairman in 1935–36), and his son, Wayne (left).

AREA COORDINATORS, NEWLY APPOINTED by the Sections Board, gathered in Chicago to exchange experiences and information on Section needs and information-requirements.

The group decided upon issuance of a periodical news letter for circulation among all 15 coordinators . . . with J. N. Overwein (coordinator for Cincinnati, Indiana, and Dayton) as editor.

Those at the meeting shown in the picture above are: P. F. Allmendinger (Stewart-Warner) coordinator for Chicago, Ft. Wayne, and Rockford-Beloit; Bernard E. Ricks (Thompson Products) for Detroit, Mid-Michigan, and Western Michigan; George J. Liddell (Sun Oil) for Philadelphia and Williamsport; Sections Board Chairman W. F. Ford; R. E. Autheil, (Inland Mfg.) who represented Coordinator Overwein; F. B. Esty (Wisconsin Motor) for Milwaukee and Twin City; and R. W. Hogan (Ethyl Corp) for Metropolitan, Syracuse, and Mohawk-Hudson.

Coordinators not present: R. K. Blakeslee (American Bosch) for New England and Southern New England; A. D. Gilchrist (Leece-Neville) for Cleveland, Pittsburgh, and Buffalo; M. F. Kent (Garrett Corp.) for K. C., Wichita, and Mid-Continent; F. D. Applegate (Convair) for San Diego, S. Calif., Salt Lake, and N. Calif.; Alex L. Gray (Gray Forgings & Stampings) for Ontario and Montreal; L. C. Kibbee (American Trucking Assoc.) for Baltimore, Washington, Virginia, and Atlanta; O. E. Kirchner (Boeing) for Oregon, Northwest, Spokane-Intermountain, Alberta, and British Columbia; and E. P. Warren (Warren & Co.) for Texas, Texas Gulf Coast, and South Texas.

A LUNCHEON HONORING JOHN A. C. WARNER on his completion of 30 years as Secretary and General Manager of the Society of Automotive Engineers was given by the SAE Board of Directors after its June 10 meeting. President Chesebrough presided. At the speakers table were Mrs. Warner, Dora Cella, and SAE Past Presidents George Delaney, W. S. James, A. T. Colwell, Ralph Teetor, Leonard Raymond, W. C. Creson, and D. P. Barnard IV. Past-President Teetor (shaking hands with John Warner) was a member of the SAE Council which appointed Warner SAE Secretary and General Manager 30 years ago.

AT TECHNICAL SESSIONS . . .

PLASTIC-CLAD METALS are examined by engineers who heard W. G. Cryderman (facing forward) describe a new approach to coating steel with vinyl films. At the same session, W. R. Pascoe (right) provided tangible evidence of fusion bond coatings, a new technique for cladding metal with plastic.

IDEAS ON WHAT'S NEW IN HEAT TREATMENT were given by J. H. Shoemaker (center) who points out the effects of a new nitriding process which increases wear and fatigue resistance. At right, differences in hardness patterns wrought by a new polyvinyl alcohol solution are shown by P. E. Cary (right), who co-authored a paper with E. O. Magnus and A. S. Jameson.

AUTOMOTIVE SPRAG CLUTCHES were displayed in connection with a paper on their design and application by E. A. Ferris, who is shown above prior to the Transmission Workshop sessions.

VEHICLE WASHING EQUIPMENT was inspected by those attending the Vehicle Washing and Appearance Maintenance session. Co-authors R. W. Burrill (third from right) and C. P. Ross (at extreme right) join in discussion which followed.

EVERYTHING UNDER ONE ROOF — for the first time in recent years, the entire January 1961 SAE Annual Meeting will be housed under **one** roof — thanks to Detroit's spacious new Convention Center, the largest in the world.

The technical program has been greatly expanded to take advantage of the enlarged physical facilities, and the Meeting is being called the **SAE INTERNATIONAL CONGRESS AND EXPOSITION OF AUTOMOTIVE ENGINEERING.**

SAE announces its INTERNATIONAL CONGRESS and

FOR THE 1961 SAE ANNUAL MEETING, the Society of Automotive Engineers is scheduling the largest conclave of engineers ever assembled to view and to discuss ground and flight vehicles. It will be held next January 9–13 at Cobo Hall in Detroit, Mich.

The event — to be called the SAE International Congress and Exposition of Automotive Engineering — would feature more than 500 displays by suppliers to the aircraft and automobile industries in the 200,000 sq ft Exposition.

More than 15,000 automotive engineers from all parts of the world are expected to be in attendance.

SAE President Harry E. Chesebrough has pointed out that "What is significant about the SAE International Congress and Exposition is that it will bring together in one place and at one time the key engineers from the entire world, who will preview automotive engineering for the era ahead.

"Engineers are casting their eyes on such sophisticated concepts as fuel cells and nuclear propulsion. Although these ideas sound like something out of a Buck Rogers section of the comics, they are getting serious study in scientific laboratories in research centers.

"Many of these exotic engineering concepts will be disclosed at the Congress."

THEME:

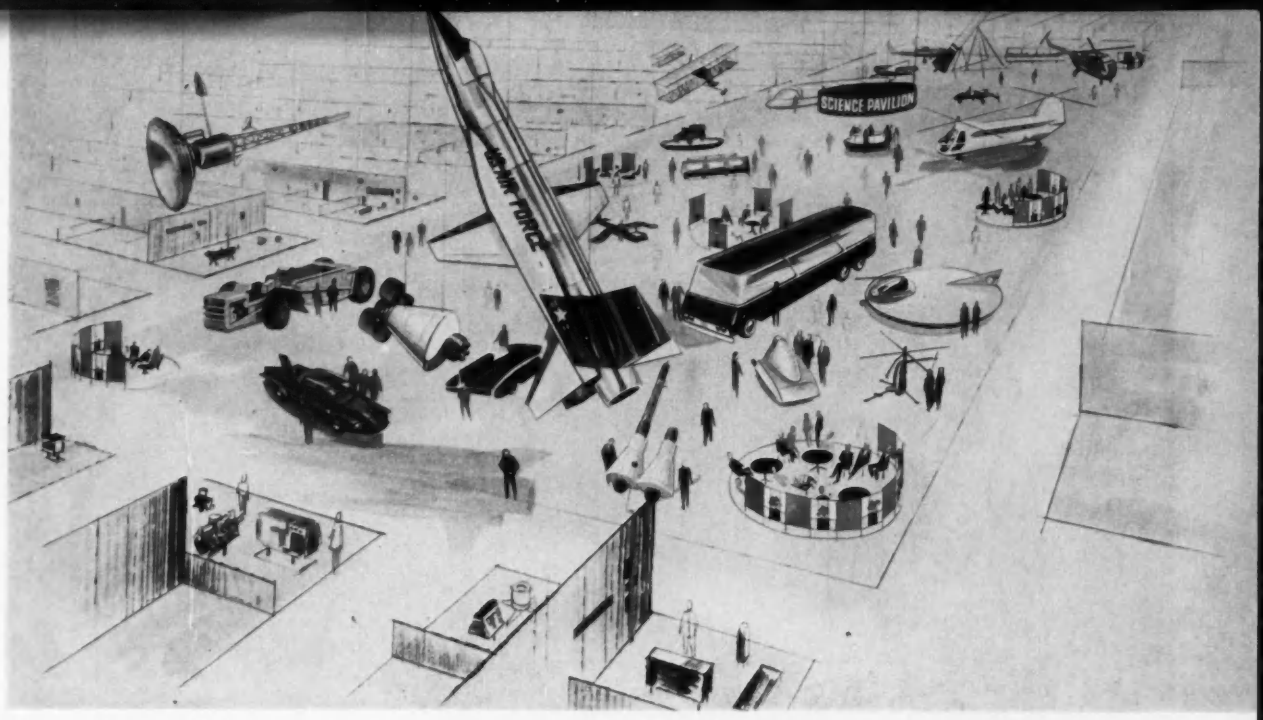
"BREAKTHROUGHS IN THE 60's"

The thirst for the latest in engineering and scientific knowledge stimulated by the mushrooming of engineering and research activities in the automotive industries has greatly expanded SAE's output of information. Over 60 technical sessions are currently being programmed for the Congress.

Each branch of the Society has examined the recent advances in its field and planned one or more sessions on the implications of the advances for the next decade. This gives the Congress its theme: "Breakthroughs in the 60's."

For example, there will be an all-day symposium on "How will the passenger travel in mass transportation on 100–200 mile trips in the late 1960's?" Vehicles to be considered include ground-effect machines, monorail cars, V/STOL craft, "preprogrammed people pods," and possibly even "flying bicycles" and antigravitation devices . . . as well as buses, trains, and conventional aircraft.

Other "Breakthroughs" sessions will cover trucks to travel future highways, road-building equipment for preparing the future highways, successors to the



THE SCIENCE PAVILION — A 20,000 sq ft noncommercial display and lounge area in the center of the Exposition will augment visually for the Congress and Exposition audience the technical advances envisioned and discussed in the sessions. It will include the X-15 experimental airplane, new wheel-less vehicles that glide on a cushion of air, a model of the highway that drives your car for you, new engines with no moving parts, and exhibits of scores of other advanced devices and techniques.

EXPOSITION of AUTOMOTIVE ENGINEERING

piston engine and their effect on vehicle design, steels for the supersonic aircraft and other vehicles of the future, new nonferrous and nonmetallic materials, and tools for "hot labs."

The sessions are being planned by the Society's 15 Activity Committees, which function under the SAE Engineering Activity Board. EAB Chairman Harry F. Barr and the EAB Executive Committee are responsible for overall planning. They have named an Operations Committee to take charge of special events at the Congress.

ACKERMAN HEADS OPERATIONS

Paul C. Ackerman, vice-president of engineering for Chrysler Corp. will serve as chairman of the Operations Committee. Mr. Ackerman recently commented, "One of the most significant services SAE offers is the opportunity for interaction among active, creative engineering minds. Bringing together under one roof the 15,000 engineers and scientists expected at Cobo during the week of January 9–13 promotes as never before the opportunity for cross-fertilization of engineering minds."

SCIENCE PAVILION

One of the highlights of this event will be the Science Pavilion, a noncommercial display in the center of the Exposition featuring examples of the latest technical developments in automotive engineering. It will include the X-15 experimental airplane, new wheel-less vehicles that glide on a cushion of air, a model of the highway that drives your car for you, new engines with no moving parts, and exhibits of scores of more advanced devices and techniques. Chairman of this feature will be Alex L. Haynes, director, Engineering Research and Advanced Product Study Office, Ford Motor Co.

INTERNATIONAL
S·A·E
AUTOMOTIVE ENGINEERING
CONGRESS·EXPOSITION

HARRY E. CHESEBROUGH, left, President of the Society of Automotive Engineers, inspects Detroit's new Cobo Hall, the site of the **SAE INTERNATIONAL CONGRESS AND EXPOSITION OF AUTOMOTIVE ENGINEERING,** with **PAUL C. ACKERMAN,** Chairman of the Operations Committee for this event. The dates are January 9-13, 1961. Chesebrough is vice-president and general manager of Plymouth-DeSoto-Valiant Division of Chrysler Corp.; Ackerman is vice-president of engineering for Chrysler Corp. It is expected that more than 15,000 automotive engineers from all parts of the world will attend the Congress and inspect the 500-booth Exposition.

About the SAE Congress next January,

PRESIDENT CHESEBROUGH SAYS . . .

IN ANNOUNCING the SAE International Congress and Exposition at a recent press conference, SAE President Harry Chesebrough noted:

"There is an element of great significance to engineers and to industry in the forthcoming International Congress and Exposition of Automotive Engineering.

"The vehicles that we know, both on the ground and in the air, will undergo greater and faster technical change in the next decade than ever before in any similar period. New knowledge which science, scientists, and researchers are uncovering will enable the engineers who design and produce our ground vehicles to make these machines more efficient, more reliable, and better suited to the transportation needs of our people.

"What is significant about our International Congress and Exposition is that it will bring together in one place and at one time the key engineers from the entire world who will preview automotive engineering for the era ahead.

"At Detroit's convention center next January, we will bring together men with common interests from countries the world over. This will provide the medium of interchange to the degree and extent which has never before taken place in our technical field.

"This cannot help but accrue dividends to our American scientists, researchers and engineers as well as to the organizations with which they are affiliated. This cannot help but be reflected in the transportation vehicles which our engineers are responsible for developing, designing, and producing.

"It is our firm belief in SAE that the world cannot help but gain when we share technical information and fundamental knowledge. This has been the concept on which our Society has grown and made increasingly greater contributions to the technologies represented by the term *automotive engineering*.

"The International Congress and Exposition of Automotive Engineering symbolizes a new approach to technology, and brings us to the threshold of new and greater accomplishments in transportation machines. We truly believe that the free, selfless exchange amongst engineers which this Congress and Exposition will foster, paves the way for greater mutual understanding."

FACTS . . .

. . . from SAE literature

(Except where a charge is specifically indicated, SAE Journal will be glad to supply on request one copy of any of the pieces of SAE literature described. Address "Literature," SAE Journal, 485 Lexington Ave., New York 17, N. Y.)

BREAKTHROUGHS IN THE 60's . . . a crystal ball look through the next decade (orally and visually) . . . is what SAE is preparing for its International Congress and Exposition of Automotive Engineering in Detroit's new Cobo Hall, Jan. 9–13 (the 1961 Annual Meeting).

A just-out booklet tells how noncommercial exhibits in the 20,000 sq ft Science Pavilion will tie in with the 15 special "breakthrough" programs — and of the more than 25 papers to be presented by overseas engineers. (Over 60 technical sessions are planned, incorporating 150 papers.)

A detailed layout of the 550 Engineering Display booths is included — with the cost of each booth.

Title of the booklet: "SAE International Automotive Engineering Exposition."

THE MOTOR VEHICLE INDUSTRY'S STAKE IN SAE is the title of a booklet which tells how industry is served through the SAE Cooperative Engineering Program.

HOW TO PREPARE GOOD SAE TECHNICAL REPORTS is a vital part of the information contained in the recently prepared "SAE Technical Committee Guideposts."

"Guideposts" outlines the principles of SAE Technical Committee operation, and has been distributed to everyone on the SAE Technical Board, its council, and committees. It will be described more fully in the August SAE Journal.

Zeder Cited for 37 Years in Industry

JAMES C. ZEDER and Mrs. Zeder view a plaque presented by Chrysler's Vice President for Engineering, P. C. Ackerman, on behalf of Zeder's "friends and associates in education, the engineering profession, the automotive industry, and Chrysler Corp." The inscription reads: "In appreciation for his humanity, devotion, judgment and professional skill through years of accomplishment that have lastingly enriched his profession, the cause of higher education, the growth of his company, the stature of the automotive industry, and the scientific goals of his country."

Zeder's retirement was occasion for a "Recognition Dinner" at Detroit Golf Club on April 26 . . . where 300 of his Chrysler colleagues and other associates gathered to honor him for his 37-year contribution to industry and education. Thirty-five of these years were spent with Chrysler, where he retired from the vice-presidency on April 30.

YOU'LL . . . be interested to know . . .

TADAMASA YOSHIKI, A MEMBER OF OUR OWN SAE, is vice-president of the Society of Automotive Engineers of Japan, Inc. Recently he wrote to SAE headquarters in New York telling how SAE's counterpart in Japan came into being.

The story goes back to 1947, when Japanese automobile and aircraft factories were inoperative and many engineers were out of work. A group of top-flight engineers, who met to discuss the situation, concluded that the only way to keep their industry alive and to make their own living would be through a coalition of engineering brains. "For this purpose," Yoshiki said, "we decided to make an organization just like the SAE in the United States."

They talked it over with an SAE member, Dr. Francis J. Scarr, then director of the Motor Transport Division, U. S. Army, Civil Transport Section, GHQ in Japan, and a society under the Japanese name of Jidosha Gijutsu Kai was founded on Feb. 1, 1947. "The Society was inaugurated, Yoshiki said, "under the unwavering principle that it would be a society of individuals, all officers would be chosen by election" — and that it would cooperate with but not be influenced by the Government. The Japanese Society now has 4000 members.

First president of SAE Japan was Dr. G. Ashara. The founder of Toyoda Motors, K. Toyoda, was the second. Yoshiki was deputy-president for a period after the death of Ashara, until the election of N. Kusunoki, of Isuzu Motors . . . and he was followed by M. Takezaki, of Daihatsu Motors. E. Toyoda, of Toyoda Motors, is now president.

The Japanese Society holds three national meetings a year — in Tokyo in the Spring and Fall, and one (similar to our Summer Meeting) in a scenic locality. Section meetings are held several times a year in Tokyo, Nagoya, and Osaka.

· · · Rambling

Through The Sections

GUARANTEED MAINTENANCE benefits both the manufacturer and owner of a vehicle, Robert Hamilton of Mack Trucks, Inc. stated at **PHILADELPHIA SECTION.**

The manufacturer can plan maintenance and repair work, and thereby absorb overheads at his service station and obtain greater profits.

The owner is insured against excessive costs through a fixed maintenance charge, is assured of maximum vehicle availability, and is relieved of all personnel and supervision problems.

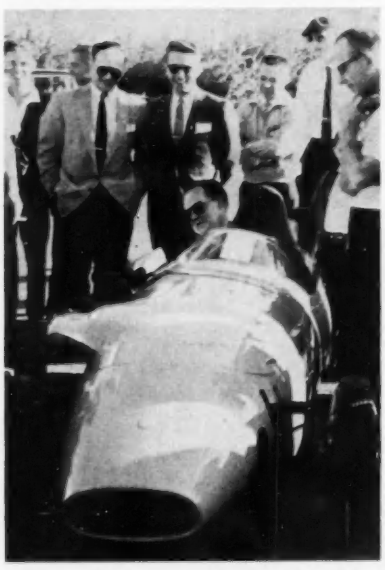
THERON P. CHASE, retired, received a certificate in recognition of his 50-year membership in SAE at **DETROIT SECTION** meeting May 9.

NELSON H-63C ENGINE, a new power plant for application in a one-man helicopter, is the first two-cycle, air-cooled engine to have **FAA** Certification and to meet military specifications. The engine, which has been adapted for use in Hiller and Gyrodyne helicopters was originally designed for use as auxiliary power for gliders, Theodore Nelson, owner of Nelson Specialties, told **NORTHERN CALIFORNIA SECTION** April 27.

TWA BOEING 707 SIMULATOR includes over 1600 electronic tubes and 118 miles of wiring. The simulator is capable of accurately reproducing sight effects through closed circuit television, actual aircraft noise, feel and acceleration, Lloyd L. Kelly of General Precision, Inc. told **KANSAS CITY SECTION** May 19.

FRAME MOUNTINGS of large, slow-speed engines in both stationary and marine applications must allow the base to shift under the engine to prevent the settling of concrete bases or torsional bending of ships from imposing stresses on engine castings, Paul J. Louzecky of Nordberg Mfg. Co. told **ST. LOUIS SECTION** May 2.

He also mentioned the corrosion of copper-lead bearings. Oxidation of lubricating oil will cause it to become acidic, at which point it will start dissolving lead in the bearings. The oil is tested monthly for corrosivity. Usually it lasts from four to five years — the equivalent of 1,000,000 miles in a passenger car.



The 1960 model Stanquelline Formula I Racing Car from Italy (above) was one of the vehicles displayed at **BUFFALO SECTION'S** seventh annual Concourse d'Elegance meeting which was held May 18.

TO PREVENT EQUIPMENT FAILURE and save money, adopt a practical maintenance program which follows a systematic replacement of parts and lubricants, L. O. Eckhardt of Mack Trucks, Inc. told **BRITISH COLUMBIA SECTION** April 20.

Sections Present Student Paper Awards

Winners of CLEVELAND SECTION'S student paper contest receive their awards from Section Chairman E. H. Scott. (Left to right) **R. H. Teare** of Case Institute of Technology won first place. Robert L. Mentzer of Case and Robert N. Hepworth of Fenn College won runner-up awards.

• • •

A STRING OF 60 TON GONDOLA RAILROAD CARS girdling the earth at the equator two and one-half times would be necessary to hold all the excavation from the Saint Lawrence Seaway Project, John Beukema told **WESTERN MICHIGAN SECTION** May 3.

At some locations the cost of excavation has raised from $0.36 to $2.50 per cu yd, due to unforeseen difficulties such as blue clay miring down equipment to limestone requiring fire jets at 4000 F and five times speed of sound to drill for dynamite holes.

Beukema is a member of Advisory Board of Saint Lawrence Seaway Corp., a position appointed by President Eisenhower.

Winners of the annual student technical essay contest sponsored by **WESTERN MICHIGAN SECTION** are: (back row, left to right) Donald J. Sabourin and William T. Withey of Aquinas College, Jack C. Olthius and Jonathan E. Nibbelink of Calvin College, (front) Raymond Boven and Richard L. Boulard of Grand Rapids Junior College, and Marlin G. Bensinger and Robert C. Anderson of Muskegon Community College.

PROJECT MOLOKAI is a $1,500,000 development which will furnish aggregate for large building projects under construction or being planned in Hawaii. The development utilizes a sand supply located on the Island of Molokai sufficient to supply Hawaii for two or three generation, a volcanic cinder supply from a young mountain near Hale-Alono Harbor which will last for 40 years, and a rock supply at the Harbor sufficient to last for 25 years. (Water haul from Hale-Alono to Honolulu Harbor is only 42 miles.)

Nitromond, a form of commercial fertilizer, was used, with a small amount of dynamite for a primer, as a special blasting material to increase the draft permissible in the approach to the harbor, R. L. Muller of Honolulu Construction & Draying Co. told **HAWAII SECTION** May 17.

Brown McKown R. Short Mrs. Short Melia Landers

THE MAC SHORT AWARD was presented to **Elliott D. Brown** of California Polytechnic College for his paper "Design, Construction and Testing of a Regenerator For A Solar Mars Gas Turbine" at **SOUTHERN CALIFORNIA SECTION** May 9. The presentation was made by Mrs. Mac Short and Richard Short, widow and son of Mac Short.

Four students papers were submitted in the competition. The other three students, who were introduced in recognition of their outstanding work, were: Charles L. Landers, Northrup Institute of Technology; Peter F. Melia, California Polytechnic College; and Ross D. McKown, Loyola University.

SAE MEMBERS

Hurley

Burton

Huebner

Geniesse

ROY T. HURLEY has retired as chairman, president, and director of Curtiss-Wright Corp., "at his own request in order to devote his entire attention to the development of new products."

EDWARD F. BURTON has been named vice-president of engineering at Douglas Aircraft Co., Inc. He is succeeding **ARTHUR E. RAYMOND** who retired June 1.

A Douglas veteran of 35 years, Burton has had a key role in the design of every plane in the DC series. He was most recently vice-president, engineering, transport aircraft systems.

ARTHUR W. JUDGE, author of numerous books on internal-combustion engines, has recently had published a new volume, "Small Gas Turbines and Free-Piston Engines." It deals with gas turbines ranging from the smallest models of 30–40 bhp up to 1000–1500 bhp, but with the emphasis on engines of medium output. The book covers many applications of these turbines — other than aircraft — with a whole chapter devoted to automobile gas turbines. There are also chapters on the free-piston-turbine engine, combustion and fuel systems, and materials for gas turbines. The 328-page volume is published by Macmillan, New York, price: $10.

EDWARD N. COLE, a vice-president of General Motors Corp., and general manager of Chevrolet Division, has been named co-chairman for chapter solicitation of the 1960 Torch Drive. He will organize, train and direct volunteer workers in five solicitation units which traditionally raise between 80 and 90% of the Torch Drive total.

GEORGE J. HUEBNER, JR., executive engineer for research at Chrysler Corp.'s Engineering Division, has been elected president of the Chrysler Institute's board of trustees, succeeding **JAMES C. ZEDER.**

Huebner's new responsibilities will be in addition to his duties as head of the research section. He has served since 1947 on the Institute's board of trustees and board of administration.

The board of trustees also elected two new trustees: **ALAN G. LOOFBOURROW**, director of engineering, and **ERNEST P. LAMB**, executive engineer for administration.

Continuing as trustees are: **P. C. ACKERMAN**, vice-president of engineering, **L. R. BAKER**, director of the Institute, **H. E. CHESEBROUGH**, corporate vice-president and general manager of Plymouth-De Soto-Valiant Division, and Huebner.

J. C. GENIESSE retired last month as manager, product development and technical services, Atlantic Refining Co., Philadelphia. He is now on an extended trip through Europe, during which he attended the Passion Play at Oberammergau late in June. When he returns, he will live in Collegeville, Pa., where he purchased a home several years ago.

Geneisse has been active in SAE and CRC throughout his career, and has held many posts of responsibility in both organizations. He is a past SAE Director and a past Chairman of Philadelphia Section.

FRANK W. WYLIE, director of public relations for Dodge Division, Chrysler Corp., has been elected chairman of the Motor Truck Public Relations Committee of the Automobile Manufacturers Association.

ALAN G. LOOFBOURROW, director of engineering for Chrysler Corp., received the Benjamin G. Lamme Medal June 10 during Ohio State University's commencement exercises. The award has been presented annually since 1931 to a graduate of the university for "meritorious achievement in engineering or the technical arts."

W. C. NEWBERG, president of Chrysler Corp., has announced the consolidation of corporate manufacturing staff and services and related activities under **B. W. BOGAN**, vice-president. **JOHN E. BRENNAN**, vice-president, corporate manufacturing staff and services, with responsibility for manufacturing engineering, industrial engineering, quality control, inter-plant transportation and plant protection, will report directly to Bogan, who will continue to direct purchasing and supplier relations, and organization, and general staff operations.

J. CHASE FIELDING, a past chairman of Washington Section, has been named a vice-president of Airaterra. Long active in the aircraft and missile field, he is manager of Airaterra's Government Division with headquarters in Wash., D. C. He was named to the Airaterra Board of Directors last year.

JOHN C. HOLLIS, manager, Administrative Division at SAE headquarters, will serve as student advisor for the 1960 Third Year Fundamentals Course of the Institute of Organization Management's mid-summer session at Syracuse University, July 31 through Aug. 6.

The third-year Fundamentals Course serves as a bridge from fundamental "know-how" courses to the Advanced Management Studies, where greater stress is placed on principles in practice.

JAMES K. MARECHAL, JR. has been named executive vice-president of Management Directors Co. Formerly he was director of special projects for Warner Technical Publications, Inc.

Marechal is currently working on the formation of a scientific and engineering company which will be called Galayie Scientific & Engineering Co.

E. W. FULLER has been appointed manager of special products division at Lockheed Aircraft Corp.'s Georgia Division. Fuller joined Lockheed's Georgia Division in 1955. His initial assignments were in the preliminary design and operations research divisions. Later, he became directing staff engineer of ground support equipment and maintenance design staff.

DONALD H. SPICER has become president of Spicer Sales, Inc. Previously he was vice-president of sales for Ferry Cap & Screw Co.

N. C. Barnard Wins Lacrosse Honor

NORRIS C. BARNARD was elected to the Lacrosse Hall of Fame last February . . . the 19th man to be so honored.

Barnard's lacrosse career spans more than 20 years and six organizations. He played three years at Swarthmore and managed the team for one. He played seven years with Crescent Athletic Club in Brooklyn and was captain of the team one year. Then followed two years with Philadelphia Lacrosse Club; six years with Penn Athletic Club (captain one year); and three years with Montclair Athletic Club in New Jersey (captain one year).

Barnard is also actively interested in the U. S. Power Squadrons, an association of some 50,000 yachtsmen and others interested in promoting high standards of navigation and seamanship.

He has been with Esso Standard Oil Co. since 1935 — and is presently manager of Shallow Draft Marine Sales. He joined the Society in 1937.

CHARLES S. WAGNER, executive assistant to executive vice-president, has been named assistant general manager of Georgia Division of Lockheed Aircraft Corp.

DONALD R. MENTLIKOWSKI has joined FWD Corp. as senior designer. Formerly he was mechanical engineering analyst for Research Designing Service.

EUGENE V. GRUMMAN, chief engineer of Bullard Co., spoke on "High-Quality" — thru — "People in Quality — Quality in People" at the 14th Annual Convention of American Society for Quality Control which was held in San Francisco, May 24–26.

MEL GORDON has become president of Standard Batteries, Inc. Previously president of Mel Gordon General Tire Co., he has sold his interest to General Tire & Rubber Co.

A. E. JOHNSTON has become defence production officer for the Canadian Department of Defence Production with headquarters at Wright-Patterson Air Force Base. Formerly he was associated with Avro Aircraft, Ltd.

Continued

Bogan

Brennan

Fielding

Teetor Honored by Pennsylvania Alumni

SAE PAST PRESIDENT RALPH R. TEETOR, director and former president of Perfect Circle Corp., received the "Man of the Year" award from the University of Pennsylvania Alumni Club of Indiana.

The award was made at a dinner April 20 honoring Dr. Harnwell, president of the University.

Commenting on the award, Harnwell stated, "It is the stature of men like him which lends continuing distinction to the University of Pennsylvania."

Sutherland

Ludvigsen

Whitlock

ROBERT L. SUTHERLAND, professor of mechanical engineering at the University of Wyoming since 1958, has been named head of the University's mechanical engineering department.

E. L. LUDVIGSEN, president of Fuller Mfg. Co., has been elected to the board of trustees of Tri-State College, Angola, Ind.

MARVIN WHITLOCK has been named senior vice-president for operations and maintenance at Capital Airlines, Inc. He will assume his new post in addition to his present position as senior vice-president for maintenance and engineering.

MARK J. O'CONNELL has become manager of Standard Products Division of Old Dominion Iron & Steel Corp. Previously he was sales manager of Heat Exchange Division for Young Radiator Co.

H. G. TOWNSEND has been appointed assistant to the manager at AiResearch Mfg. Co. Previously he was employed by Thompson-Ramo-Wooldridge, Inc. as manufacturing manager of their West Coast Division.

JAMES SHELBY BOWRON has become a partner for Black-Bowron Investment Co. Previously he was vice-president of Dixie Drive It Yourself System.

H. FLETCHER BROWN has joined Lockheed Aircraft Service as vice-president and assistant to president. Previously he was assistant general manager of Georgia Division, Lockheed Aircraft Corp.

NORMAN E. JANKE has become senior designer for Chevrolet Motor Division at GMC Engineering Center. Formerly he was supervisory engineer for Ainsworth-Precision Castings Co.

BRUCE G. BOOTH of General Motors Corp.'s legal staff has been elected chairman of Committee on Vehicle Regulation of Automotive Manufacturers Association.

GEORGE V. MERCER, formerly field representative in Chicago, is now regional manager of field engineering with headquarters in Kansas City for Lord Mfg. Co.

WILLIAM J. COLSON has become manager of Defense Products Division at Brunswick Corp. Formerly he was factory manager for Brunswick-Balke-Collender Co.

J. A. JOYNER has become manager of technical service for Cummins Engine Co., Inc. Previously he was chief engineer for Curtiss-Wright Corp.'s Utica Division.

WILLIAM EARL SMITH, formerly employed by Sargent Engineering Corp., has joined the staff of Hydraulic Research & Mfg. Co. in Burbank, Calif., as application and sales engineer.

ALAN BOTT, formerly axle engineer in Fort Wayne, is now sales engineer in Toledo for Dana Corp.

ANDREW J. GREGA has joined Acoustica Associates as senior electronic engineer. Formerly he served Stellardyne Laboratories, Inc. as staff engineer.

JOE D. WILSON has been appointed mechanical engineer for Hercules Powder Co. Previously he was a mechanical engineer for the U. S. Navy Civilian Service.

F. W. MELLOR, JR. has been appointed field sales manager for Goodyear Aircraft Corp. Formerly he served Goodyear as manager, Manufacturers Products Division, customer relations.

GEORGE E. TUBB has been named director of marketing at Electro-Tec Corp. Formerly director of marketing at Laboratory for Electronics, Boston, Tubb was a management and marketing consultant immediately prior to joining Electro-Tec Corp.

OTTO R. LAST has joined Pettibone-Mulliken Corp. as industrial sales representative. Previously he served Amphenol Borg Electronics Corp. as industrial engineer.

W. E. BURNETT has been named manager of Hull, Powertrain, and Suspension Department, Ford Motor Co. His former position was manager of Engine Department, M-E-L Division.

HENRY G. HOWELL, formerly mechanical engineer for Lockheed Aircraft Corp.'s Georgia Division, is now engineer and writer for Lockheed's Missile Systems Division.

MATHEW D. GARRED, JR., previously an engineer for General Electric Co.'s Jet Engine Department, is now an engineer at their Locomotive and Car Equipment Department.

HENRY HAROLD HART has joined the Kansas City Water Department as civil engineer. Previously he was project engineer for Westinghouse Electric Corp.

T. D. STAY, technical advisor for Reynolds Metals Co., received The Joseph S. Seaman Gold Medal Award from the American Foundrymen's Society at their Annual Banquet May 11 held during the 64th AFS Castings Congress and Exposition at the Hotel Sheraton in Philadelphia.

EDWARD F. HANNON has become chief engineer for Precision Castings Co., Fayetteville, N. Y. Division of Precasco Corp. Previously he was assistant chief development engineer at Ainsworth-Precision Castings Co.

R. J. SCHNELIER has joined Rohn Drye & Associates, Inc. as consulting engineer. Previously he was assistant base engineer at the Columbus Air Force Base in Miss.

ALLEN R. STOKKE has been appointed branch manager at Detroit for Garrett Corp. Formerly he was senior sales engineer in Dayton, Ohio.

LORING F. NIES has become project engineer for Dresser Mfg. Division of Dresser Industries. Formerly he served Chrysler Corp.'s Engineering Division as senior studio engineer.

GEORGE ROBERT WILLIAMS, previously structures engineer for North American Aviation Corp., is now sales engineer at Heliport Division of Beckman Instruments, Inc.

JOEL H. LEET has joined the Cheyenne Division of Electro-Mechanical Systems, Inc. as field supervisor. Previously he was associate engineer for Douglas Aircraft Co., Inc.

K. G. WILLIAMS has become development engineer, engine at Willys Motors, Inc. Previously he served Ford Motor Co. as unit supervisor, product study vehicles.

KENNETH P. BOWEN has joined The Martin Co. as director of their Manufacturing Division. Previously he was vice-president of manufacturing at Northrop Aviation Corp.

DAVID RAY COOK has joined the Convair Division of General Dynamics Corp. as design engineer. Previously he was associate engineer for Douglas Aircraft Co.

DAVID H. EDWARDS is now experimental engineer for Willys Motors, Inc. Formerly he was product engineer for Ford Motor Co., Transmission and Chassis Division.

PHILIP H. FRYBERGER has become research and development staff assistant at the Wright Patterson Air Force Base, U. S. Air Force. Formerly he was staff engineer for Breeze Corp., Inc.

HARRISON T. PRICE has become operations manager for Chevrolet-Cleveland Transmission Division of General Motors Corp. Previously he was general superintendent of production at Chevrolet Motor Division.

MURRAY K. SIMKINS has been appointed editorial director of all publications at National Market Reports, Inc. and executive editor of Automotive Services Digest.

Simkins was most recently program co-ordinator for Jam Handy Organization. Prior to that he served Chilton Publications for a number of years.

Simkins

EDWARD A. HAAS has joined the staff of Automotive Shop Equipment, Inc. Since 1928 he had been on the staff of Ballou & Wright Co. in Portland, Ore. The company closed its Portland warehouse in April.

Haas is past chairman of SAE Oregon Section.

Haas

E. J. HARDIG, chief engineer for the Automotive Division of Studebaker-Packard Corp., has been appointed a vice-president of the division.

MERRILL A. HAYDEN, general manager of Machinery Hydraulics Division at Vickers, Inc., has been elected a vice-president of the company.

Hardig

T. JOSEPH KEANE has been named sales manager of Automotive and Aero Equipment Division of Russell Mfg. Co. He had been sales engineer for the division since 1952.

JOHN P. HENSON, who since April 1959 has been sales engineer in charge of Ford Motor Co. account for Dana Corp., has been named sales manager of their Universal Joint Division.

Hayden

R. WILLIAM TROXEL has been appointed sales engineer, Industrial Division, Imperial Brass Mfg. Co. Previously he was Midwest district sales manager for Flexonics Corp.

JOHN C. WALTER has been named manager of manufacturing for Cummins Engine Co., Inc. Previously he served Cummins Engine Co., Ltd. in Scotland as chief engineer. In this capacity he assisted in the organization and initial operations of the Cummins' subsidiary manufacturing plant. When he left Scotland, **S. B. HARTSHORNE** succeeded him as chief engineer.

Walter's new responsibilities include management of production engine test and final assembly operations, and the integration of these operations into a new test and assembly facility.

Keane

W. MASON WILLIAMS has been appointed general manager of Utica Drop Forge & Tool Division of Kelsey-Hayes Co. Formerly he was manufacturing manager of Tapco Group of Thompson-Ramo-Wooldridge, Inc.

— continued —

Henson

Troxel

SAE Members

— continued —

Barby

MacHoll

Jensen

Asch

Williams

Black

CHARLES E. BARBY has been appointed sales manager of the newly-established Detroit regional office of Fiber Glass Division of Pittsburgh Plate Glass Co. In this capacity he will direct sales operations for Detroit, Cleveland, Cincinnati, and Buffalo district offices, in addition to continuing as manager of automotive sales.

JAMES F. MacHOLL has been appointed vice-president of engineering for Automotive Division of Electric Storage Battery Co. Previously he was director of engineering.

ARLING H. JENSEN, chief service engineer for Sealed Power Corp., spoke June 2 at the Automotive Engine Rebuilders Association convention on "Abrasive Wear — Identification and Prevention."

E. L. ASCH has been appointed director of sales training for Vickers, Inc. Previously he was in charge of the company's Houston, Tex. sales office. He has had 20 years of experience with Vickers, including both engineering and sales responsibilities.

HARRY WILLIAMS, vice-president in charge of sales for Automotive and Aircraft Division, American Chain & Cable Co., Inc., has been elected a member of the board of directors.

J. C. BLACK has been appointed manager of automotive products at Thermoid Division of H. K. Porter Co., Inc. He will direct activities for automotive friction, rubber and hydraulic brake parts, and will have administrative responsibility for design, manufacture, performance, price and promotion of automotive products.

Previously he was product manager of heavy duty friction.

J. BRENT MALIN has become division head for E. I. du Pont de Nemours & Co. with headquarters in Wilmington, Del. In this capacity he will translate technical information into a form which is useable for the company's Sales Division. Formerly he was technical manager for western region.

ROBERT L. PONS has joined the Defense Systems Division of General Motors Corp. as project Aerodynamics Engineer. Formerly he served Convair Division of General Dynamics Corp. as propulsion specialist.

CHARLES SUTTON has been named manager of product development for Imperial Brass Mfg. Co. He had been sales manager of Arrow Tools, Inc., since 1958. For six years prior to that he served Weatherhead Co.

JOHN J. UNGER has joined Electro-Kinetics, Inc, as sales engineer. Formerly he was product engineer of Hotpoint Co., Division of General Electric Co.

HAROLD W. OTT is now sales engineer and district representative at Baltimore, Md. for J. I. Case Co. Previously he served them as assistant service manager in Racine, Wis.

GERALD A. PETERSON has been appointed director of industrial engineering at Westinghouse Airbrake Co. He will be concerned with technical phases of manufacturing and will assist in the development of cost reduction programs.

Previously he has served Ford Motor Co. in various supervisory capacities.

E. CLAUDE JETER, manufacturing manager, Foundries, Engine & Foundry Division of Ford Motor Co., has been elected a national director of the American Foundrymen's Society.

THOMAS B. WAKELAND has become resident manager in Japan for Hoover International, Inc. Formerly he was regional sales engineer in Milwaukee for Hoover Ball & Bearing Co.

HAROLD C. STONE has been named director of American Steel Treating Co.'s metallurgical laboratory. Formerly he was chief metallurgist for LeTourneau-Westinghouse Co.

S. BABCOCK has become assistant manager of space systems for Hughes Aircraft Co. His previous position was West Coast corporate representative for Republic Aviation Corp.

JOSEPH F. LEWIS, previously mechanical engineer for Bendix Mishawaka Division of Bendix Corp., is now mechanical project engineer at Hallicrafters Co., Inc.

H. T. HOKANSON has become manager of special projects at General Electric Co.'s Missile and Space Vehicle Department. Formerly he was manager of engineering for their Small Aircraft Engine Department.

HENRY Y. RUBY is now president of Empire Chevrolet, Inc. Previously he was vice-president of Atlas Lift Truck Rentals & Sales, Inc.

W. S. GRIPMAN has joined Caterpillar Tractor Co. as field representative in Florida. Previously he was sales engineer for General Electric Co.

JOSEPH R. GILLETTE has become principal design engineer at Ford Motor Co. Formerly he was concerned with product planning at their Lincoln-Mercury Division.

MAURICE W. BOLSTER, previously assistant manager, is now manager of Industrial Products Division of Shell Oil Co.

BEN E. PAPPE has joined Steakley Brothers Chevrolet Co. in the capacity of service manager.

RICHARD G. KLEIN has joined the Kawneer Co. as project engineer for mechanisms research. Previously he was project engineer for Sunstrand Aviation Corp.

JAMES MICHAEL MARZEN, formerly test and development engineer Chrysler Corp., is now automotive engineer at Standard Oil Co. of Indiana.

DUANE SHAW is now assistant chief engineer of The Rucker Co., Oakland, Calif. Previously he was senior project engineer.

WESLEY S. HARJALA, previously product development engineer at Ford Motor Co., is now liaison engineer for McCulloch Corp.

ARNOLD FINK, formerly an engineer for Esso Research & Engineering Co., is now an engineer for Aerojet-General Corp.

GILBERT L. WOLF has joined International Business Machines Corp. as planning representative. Formerly he served The Martin Co. as senior mechanical engineer.

HUGH S. ROBINSON has become president of Robinson Mfg. Co. Formerly he was chief engineer for Chicago Printed String Co.

Obituaries

DWIGHT E. AUSTIN . . . (M'38) . . . owner, Dwight Austin & Associates . . . died April 11 . . . born 1897 . . . designed Nite Coach & Buffet Parlor Car for Pickwick Coach Co., Greyhound Bus for Yellow Truck & Coach, and Post War Coach for Twin Coach.

SYDNEY BEVIN . . . (M'14) . . . retired mechanical engineer for Rider Ericssen Engine Co. . . . died May 29 . . . born 1885 . . . former mayor of Aashroken Beach, Long Island.

LAWRENCE W. FISCHER . . . (M'19) . . . executive sales engineer, Bendix Products Division, Bendix Corp. . . . died March 25 . . . born 1895.

HANS WOLFRAM SACK . . . (M'54) . . . chief engineer in charge of field test at Rheinstahl-Hanomag in Hannover, Germany . . . died May 16 . . . born 1929.

SAE Members Say:

THOMAS V. JONES, of Northrop Corp., Says Technology's Objective Must Change

"TECHNOLOGY'S traditional objective — maximum possible performance — must be converted to a more sophisticated goal, namely, performance adequate for the accomplishment of a mission objective at the lowest possible cost," Thomas V. Jones, president of Northrop Corp., said in a recent issue of The General Electric Defense Quarterly.

"It should be emphasized," he stated, "that technology must provide the high performance needed to accomplish a particular mission. *The higher challenge to technology is to enlarge its concept in a way that makes its objective not the weapon but the mission. The mission problem must be considered in the context of the total defense posture.* Instead of addressing itself *solely* to increased weapon performance it must begin to think in terms of providing (1) a force effectiveness which (2) will perform a given mission at (3) a cost which does not preclude the performance of other essential missions. This approach requires that technology develop hand in hand with concept, and that both be measured not only in terms of physical effects but also in terms of their demand on resources. Its success will depend on the development of fundamental solutions to mission problems.

Technology, instead of merely providing a solution for a given concept, must itself give birth to the concept. We must cultivate a new combination of conceptual thinking, technical research and the most effective use of resources. It will take the free interaction of these three elements to create the new kinds of solution we need."

RALPH H. ISBRANDT, of American Motors Corp., Says Vehicle Size Will Be Reduced

"THE SIZE OF THE VEHICLE is likely to be reduced in the overall (in the coming decade)," Ralph H. Isbrandt, director, automotive engineering and research, American Motors Corp., said at the 8th Highway Transportation Congress in Washington, D. C.

"Even the non-compacts," he said, "are growing somewhat smaller externally, responding to traffic flow, parking and congestion needs. The functional trend will obviously reduce overhang. . . . .

Perhaps the earliest improvement we may see will come in signal systems — for example, the possible separation of the turn signal and stop lights, to insure more positive communication of the driver's intention."

Isbrandt is chairman of AMA Engineering Advisory Committee and was 1959 chairman of SAE Technical Board.

SAE's CEP NEWS

COOPERATIVE ENGINEERING PROGRAM

Almen Works Collected by Brigham Young University

Almen

A SPECIAL collection of papers and reports by J. O. Almen, organizer and first chairman of the SAE Iron and Steel Technical Committee's Division 20, Mechanical Prestressing of Metals, has been instituted by Brigham Young University, according to Prof. W. M. Beebe of BYU. Beebe made the announcement at the May 16–18 Division 20 meeting in Colorado Springs which was attended by 50 metallurgists and engineers from all over the U. S. The collection will consist of Almen's papers and reports on metal stresses, fatigue, and shot peening as well as a set of his famous fatigue failure specimens. Many of these works have been presented at SAE meetings.

Almen, who headed Mechanical Engineering at GM's Research Laboratories at the time of his retirement, was present at the Division 20 meeting when the announcement came. His participation in ISTC work extends over two decades. Almen now leads an active life in Sierra Madre, Calif.

Other events of the 2½day-meeting were:

- A surface rolling symposium covering application, theory, stress calculations, tooling, control and inspection, effects of rolling and other prestressing.
- A forum on choosing the optimum method, intensity and coverage of mechanical prestressing.
- A technical session on new shot materials, shock forming, explosive peening, and surface conditioning by vibration.
- The regular biennial meeting of Division 20 where a subcommittee was created to develop a uniform classification system for materials used for shot peening and blast finishing. Howard Kulas, Cleveland Metal Abrasive Co., was named chairman of the new group.

G. F. Bush, Ford Motor Co., and R. H. Briggs, Eaton Mfg. Co., were unanimously re-elected Division 20 chairman and vice-chairman, respectively.

A GOLDEN ANNIVERSARY YEAR EVENT of the SAE Iron and Steel Technical Committee was a 2½-day meeting of ISTC Division 20 — Mechanical Prestressing of Metals. Held at the Broadmoor Hotel, Colorado Springs, Colo., the meeting was attended by 50 metallurgists and engineers from all over the U. S. (See Almen story above.) In first row from left to right are: C. W. Cable, G. J. Gaudaen, J. G. Roberts, F. W. Smiley, R. S. Kormarnitsky, Allyn Stillman, L. A. Campana, R. F. Brodrick, and W. D. Starrett.

In second row from left: H. J. Noble, E. W. Hawkinson, R. H. Briggs, Prof. W. M. Beebe, Division 20 Chairman G. F. Bush, J. O. Almen, J. C. Straub, D. J. Wulpi, H. O Fuchs, and H. R. Neifert.

In third row are (from left): J. L. Oberle, R. D. Behr, J. A. Main, W. J. Fuhrman, unidentified, J. E. Silvis, T. E. Eagon, George McNeile, R. M. Sahwiler, J. J. Repko, G. A. Butz, R. E. Harvie, H. D. Nagel, F. J. Crowley, Austin Phillips, R. W. Olsen, and N. E. Faas.

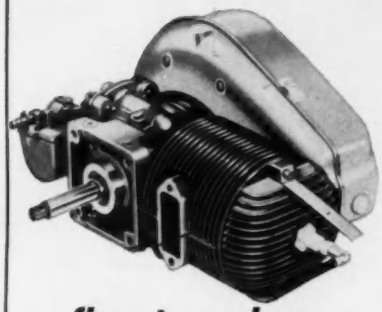
SAE NATIONAL MEETINGS

1960

- August 16–19
  National West Coast Meeting, Jack Tar Hotel, San Francisco, Calif.
- September 12–15
  National Farm, Construction and Industrial Machinery Meeting (including production forum and engineering display), Milwaukee Auditorium, Milwaukee, Wis.
- October 10–14
  National Aeronautic Meeting (including manufacturing forum and engineering display), The Ambassador, Los Angeles, Calif.
- October 25–27
  National Transportation Meeting, Hotel Leamington, Minneapolis, Minn.
- October 31–November 2
  National Powerplant Meeting, Sheraton-Cleveland, Cleveland, Ohio.
- November 2–4
  National Fuels and Lubricants Meeting, The Mayo, Tulsa, Okla.

1961

- January 9–13
  SAE International Congress and Exposition of Automotive Engineering, Cobo Hall, Detroit, Mich.
- March 13–17
  National Automobile Week (including National Production Meeting), The Sheraton-Cadillac, Detroit, Mich.
- April 4–7
  National Aeronautic Meeting (including production forum and engineering display), Hotel Commodore, New York, N. Y.
- June 4–9
  Summer Meeting, Chase-Park Plaza, St. Louis, Mo.



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Crankshaft has ball bearing on drive end; roller bearing at magneto end. Rod has roller bearings at both ends.

SPECIFICATIONS

TYPE Horizontal or vertical mounting; air-cooled; 2-cycle, clockwise or counter-clockwise rotation (at drive end).

MODELS

SERIES 390 Displacement 3.9 cu. in. Rated horsepower 1.6 at 4000 rpm.

SERIES 580 Displacement 5.8 cu. in. Rated horsepower 4.0 at 4500 rpm.

SERIES 700 Displacement 7.0 cu. in. Rated horsepower 5.0 at 4500 rpm.

IGNITION Wico flywheel type magneto.

FUEL SYSTEM Float feed carburetor is standard; diaphragm type carburetor with integral fuel pump is optional.

VALVES Reed type; corrosion resistant.

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One in a series of technical reports by Bower

BEARING BRIEFINGS

ROLLER GUIDANCE– VITAL FACTOR IN BEARING LIFE

Roller guidance has been established by the Anti-Friction Bearing Manufacturers Association as a major rating factor for roller bearings. There is a direct relationship between this factor and the life and capacity of a cylindrical roller bearing under load.

Figure 1 illustrates the results of a loose fit between a roller and the guiding ribs of the raceway. Because of lack of guidance by the ribs, the roller is free to skew and skid under load. Such a condition invariably leads to early bearing failure.

To achieve close roller fit and proper roller guidance, Bower precision grinds each bearing race on specially designed centerless grinders. In this operation, Bower positions the integral raceway ribs *from the theoretical centerline of the bearing*. This method produces bearings with high dimensional accuracy and perfect symmetry.

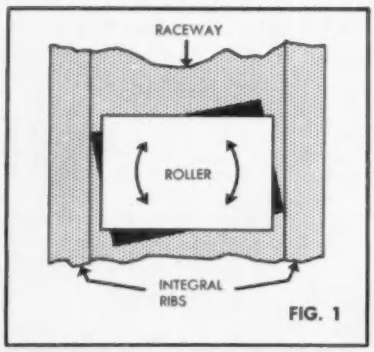
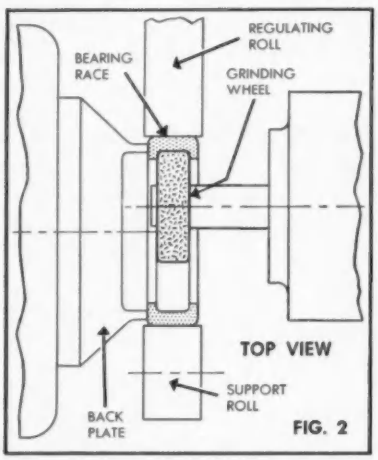
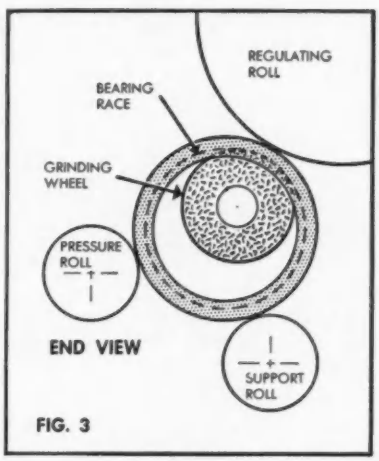


Fig. 1. Loose fit in raceway means poor roller guidance. Roller can skew and skid under load.

In addition, the close tolerances held in grinding the roller track and integral guiding ribs give Bower cylindrical roller bearings the ability to *take thrust in any direction*. A Bower cylindrical roller bearing has thrust capacity of from 10-15% of its rated radial capacity!



Figures 2 and 3 diagram the centerless grinding method used to finish Bower raceways. Use of this technique assures not only optimum roller guidance and maximum bearing life, but also virtually eliminates bearing runout. BEARING SYMMETRY WHICH RESULTS FROM THIS TECHNIQUE PERMITS ACCURATE SHAFT LOCATION REGARDLESS OF HOW THE OUTER RACE AND ROLLER ASSEMBLY ARE INSTALLED. IT COMPLETELY ELIMINATES THE POSSIBILITY OF IMPROPER INSTALLATION.



★ ★ ★ ★

Whatever your bearing needs, we suggest you consider the advantages of Bower bearings. Where product design calls for tapered or cylindrical roller bearings or journal roller assemblies, Bower can provide them in a full range of types and sizes. Bower engineers are always available, should you desire assistance or advice on bearing applications.

BOWER ROLLER BEARINGS

BOWER ROLLER BEARING DIVISION – FEDERAL-MOGUL-BOWER BEARINGS, INC., DETROIT 14, MICHIGAN

Solving Problems Of Rendezvous in Space

Based on paper by

JOHN C. HOUBOLT
NASA Langley Research Center

THE ASCENT of a satellite or space ferry so as to make a soft contact with another satellite or space station already in orbit is a problem of rendezvous in space. There will be personnel or supplies to be transferred from a ferry vehicle to a space station. A complete mission will have injection, approach, terminal, and acquisition phases, and errors in such quantities as velocity, altitude, and orbital inclination will exact penalties.

These matters are discussed in this paper, which presents the results of a study, the primary aim of which was to evaluate fuel consumption levels associated with various corrective maneuvers, and to determine the times that are suitable for initiating the rendezvous operation. The author gives equations for solving these problems and the paper is illustrated with diagrams.

To order Paper No. 175A . . . from which material for this article was drawn, see p. 6.

TRITIUM Tags Clock Lube Oil Consumption

Based on paper by

E. S. STARKMAN
University of California

TRITIUM TAGGING of the lubricating oil in an engine and scintillation counting of the resulting water of combustion make a safe, reliable method for determining lubricating oil consumption, recent studies indicate.

Application of this method to a brief CFR single-cylinder engine program showed that, under almost all conditions, ten times as much of the consumed oil left by way of the exhaust as with the blowby gases. With isooctane fuel, approximately 85% of the oil that went out with the exhaust gas was completely oxidized. Only 50% of the oil going out through the crankcase breather was completely oxidized. About 1% of the unoxidized material in the blowby gases originated from the lubricant, the remainder being from the fuel.

Coolant consumption has a disproportionate influence, increasing lubricant consumption by a factor of 100 in the range of 150 F to 375 F.

Spark setting had no discernible

continued on p. 121

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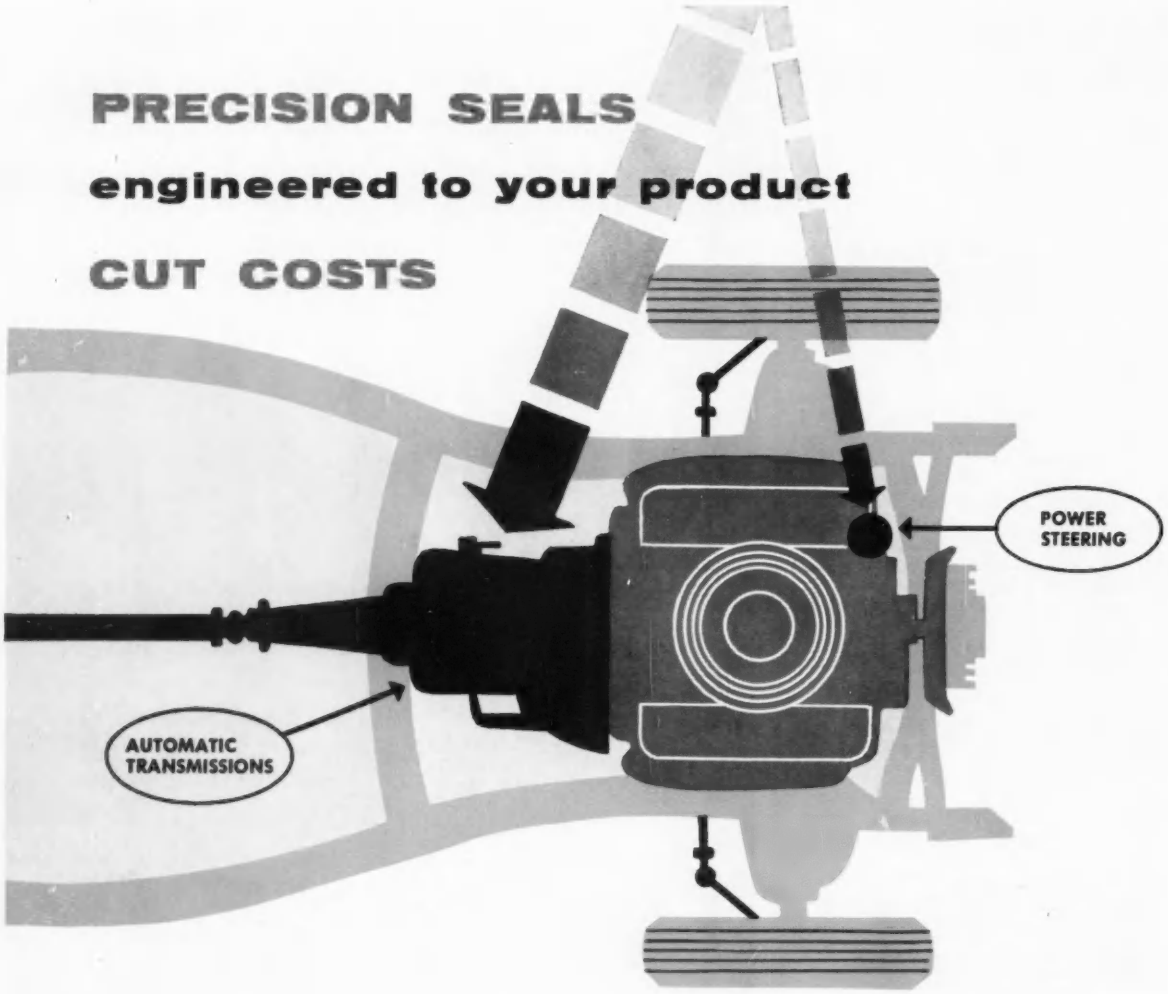

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. . . continued from p. 119 . . .

effect as long as combustion was normal. Use of the full range instead of isooctane fuel had no detectable effect on oil consumption. But it did have a major influence on the amount of unburned lubricant. It increased the amount of unburned lubricant by a factor of at least two.

Engine speed and load, unexpectedly, gave disproportionate results on oil consumption at intermediate speeds. The relationship between speed, load, and consumption was related successfully to the vibrational characteristics of the piston rings. . . . A theory was thereby derived which suggests that, under some operating conditions, abnormal oil consumption rates can be due to one or more piston rings being excited to vibration.

To order Paper No. 194B . . . from which material for this article was drawn, see p. 6.

Briefs of SAE PAPERS

continued from p. 6

High Temperature Fuel Cells, E. A. DeZUBAY. Paper No. 159E. Research program undertaken at Curtiss-Wright Corp., Quehanna, Pa., to determine most suitable electrolyte, electrode materials and configuration, materials for cell fabrication, and optimum operating conditions of temperature, gas pressures and flow rates; materials recommended; facts, observations, and conclusions drawn from analyses of all of tests run on fuel cells utilizing propane fuel, porous nickel fuel and porous silver air electrodes and ternary carbonate electrolytes.

Design and Development of General Electric CJ805-3 Thrust Reverser and Noise Suppressor, W. S. BERTAUX. Paper No. 162B. Features of thrust reverser main body of which is basically cone with cutouts extending 120° on each side which allow exhaust gas to exit from cone in reverse thrust position; two blocker doors are mounted on top and bottom of cone; development engine testing of reverser and component test programs; noise suppressor is basically corrugated type nozzle in which each corrugation must carry pressure loading of gas as it expands from turbine through nozzle discharge.

System Test GSE for Modern Weapons Systems, W. M. ALFORD, D. W. COGSWELL. Paper No. 163A. Checkout facilities forming part of ground support equipment; components are divided into control unit, signal and response unit, and air vehicle system; development of test plans for use with automatic test equipment; definition of vehicle system component functions and assignment of priority; test development, including study of stimuli, responses and combinations of functions; program development, covering tests, and trouble shooting; plan applied to model sub-system.

Boot-Strap Launching — Step Toward Simplified GSE, C. C. WORSTELL, W. A. BECK. Paper No. 163B. Details of boot-strap method as applied to horizontally stored missile system; means whereby thrust is used to erect missile before release to free flight; computer study made by Boeing Airplane Co., to determine degradation of missile performance; elevating phase of launch operation, initial flight to 5-sec elapsed time from start of thrust, and climb cruise; effect of changes for release and holding structures are evaluated separately.

Acoustically Induced Fatigue — Cause, Solution and Design Analysis, E. W. THRALL, Jr. Paper No. 164A. Paper presents fatigue problem that developed in empennage area of Navy A3D aircraft, ground and flight test programs undertaken, and results; five areas where acoustical fatigue occurred most frequently and type and size of material listed; effective solution to cracking problem found was addition of elastomer at point where cracks occurred; procedure whereby test results may be incorporated with analytical analysis to produce curves for design analysis.

continued on p. 123

These digests are provided by ENGINEERING INDEX, which each year abstracts 30,000 engineering articles from 1500 different publications and classifies them into 249 "fields of engineering interest."

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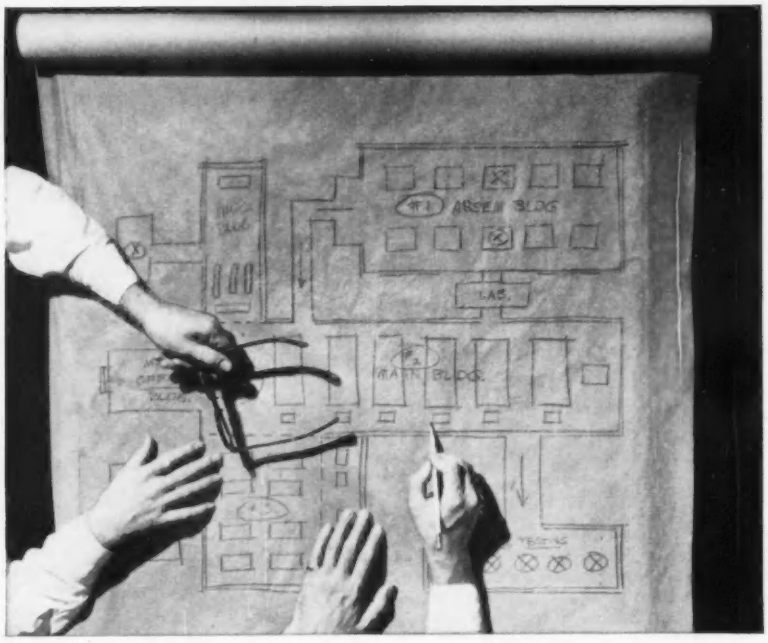

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Translucent typewriter papers are very popular of late for typed originals from which numerous copies must be made. The savings are considerable when you use translucent originals through diazo reproduction—savings up to 80% in many cases. But most translucent papers used today stand erasure very poorly. Recognizing the inevitability of human error, K&E has perfected a better translucent typewriter paper called TYPEMASTER® (193)—the perfect answer for those whose typing is less than perfect. TYPEMASTER's completely new, *engineered* surface affords outstanding erasability. A thin, unusually tough coating, it readily catches and holds the typewritten image, yet resists penetration of the ink into the paper fibers . . . and therein lies the secret of good erasability. A number of skeptics who tested the new TYPEMASTER sheets have now discarded all others. Skeptical or not – may we suggest you try it.

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Brilliant ideas often occur at random moments. For that reason, engineers on the move usually keep a tracing pad handy. But pads with soft, chipboard backing are of little use without a desk under them. That's why all K&E tracing pads are

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Briefs of SAE PAPERS

continued from p. 121

GROUND VEHICLES

Corrosion Resistance of Aluminum Automobile Engine Components, A. M. MONTGOMERY. Paper No. 147B. Engine and road tests of aluminum cylinder heads on cast iron blocks, and aluminum coolant system components on iron and all aluminum engines, by Alcoa Research Laboratories; all aluminum engine provides essentially trouble-free system; combination aluminum iron engine requires precautions in design to minimize corrosion; aluminum casting alloy which contains appreciable quantity of copper is more compatible with cast iron than other alloys.

PRODUCTION

Integrated Approach to Planning, Evaluation, and Control of Capital Facilities, C. W. GOLDBECK. Paper No. 155A. Approach by Thompson Ramo Wooldridge Inc., representing decentralized corporation with over 25 plants in United States and Canada with operations covering automated and precision small lot production, etc; outline of program phases; capital commitment procedures providing detail information for future; annual capital program giving information for evaluation of operation for ensuing year; operating forecasts developing bulk figures for 5-yr period.

Reducing Paper Mill Through Methods and Systems Simplification, H. A. HELSTROM, Jr. Paper No. 156A. Approach taken by Chance Vought Aircraft, Inc., Dallas, Tex., toward paperwork simplification; system introduced is illustrated by various examples relating to release system and procedures in handling of engineering orders, wind tunnel data card, man power control board, process chart etc; paper saving techniques available, such as use of econometric models, probability and statistics, operations research and linear programming methods.

Manufacturing Expense Controls, R. M. LYNAS. Paper No. 156B. Concepts and practices used in controlling manufacturing costs by each of four plants of Michigan Div. of Thompson Ramo Wooldridge, Inc., Cleveland, Ohio, manufacturing car and truck steering linkage, hydraulic transmission pumps, etc; use of quality control chart, daily labor performance report, allowance cards, and manufacturing budget meeting chart; examples of programs developed for getting manufacturing costs under control which are outgrowths of budget manufacturing meetings.

continued on p. 126

The buyer of an airplane with

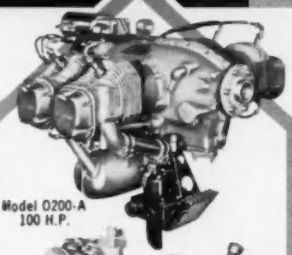
CONTINENTAL POWER

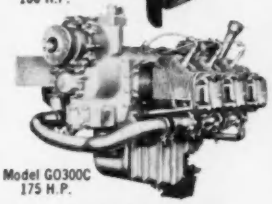
obtains two plus values available nowhere else. One is Continental's famous reliability; the other, the priceless backing of genuine Continental parts and factory-approved service no matter where he may fly.

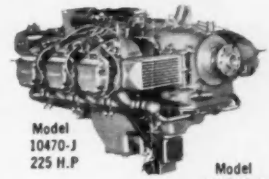
After engine dependability, the most important thing to consider in choosing an airplane is the service behind it—the facilities maintained by its makers to keep it in the air at lowest cost. And here, as on the basic score of engine stamina, planes with Continental power rate uniformly high . . . Owners of such aircraft are sure of finding genuine Continental parts and competent mechanics the world over . . . They benefit in other ways, too, from Continental's policy of backing those who build and those who use Continental-powered products.

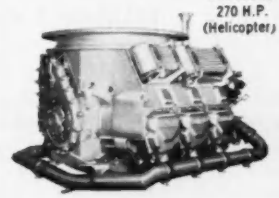
MODEL	HP	RPM	CYL.	WT.	OCTANE
A65	65	2300	4	173	80/87
C90	95	2625	4	207	80/87
O200-A	100	2750	4	190	80/87
O300-A B & C	145	2700	6	277	80/87
GO300-C	175	3200	6	312	80/87
O470-15***	213	2600	6	405	80/87
E225	225	2650	6	363	80/87
O470-K & L	230	2600	6	404	80/87
O470-M	240	2500	6	409	91/96
O470-G	240	2600	6	432	91/96
O470-H*	240	2600	6	472	91/96
I0470-C	250	2600	6	432	91/96
I0470-D	260	2625	6	426	100/115
I0470-F	260	2625	6	426	100/130
I0470-J	225	2600	6	402	80/87
I0470-K	225	2600	6	391	100/130
FSO526-A**	270	3200	6	575	91/96
GSO526-A	340	3100	6	549	91/96

*Pusher Type engine with extended propeller shaft
**Helicopter engine ***For Military use


Model O200-A 100 H.P.


Model GO300C 175 H.P.


Model 10470-J 225 H.P


Model FSO526-A 270 H.P. (Helicopter)

21 MODELS 65 TO 340 HORSEPOWER

Continental Motors Corporation

AIRCRAFT ENGINE DIVISION

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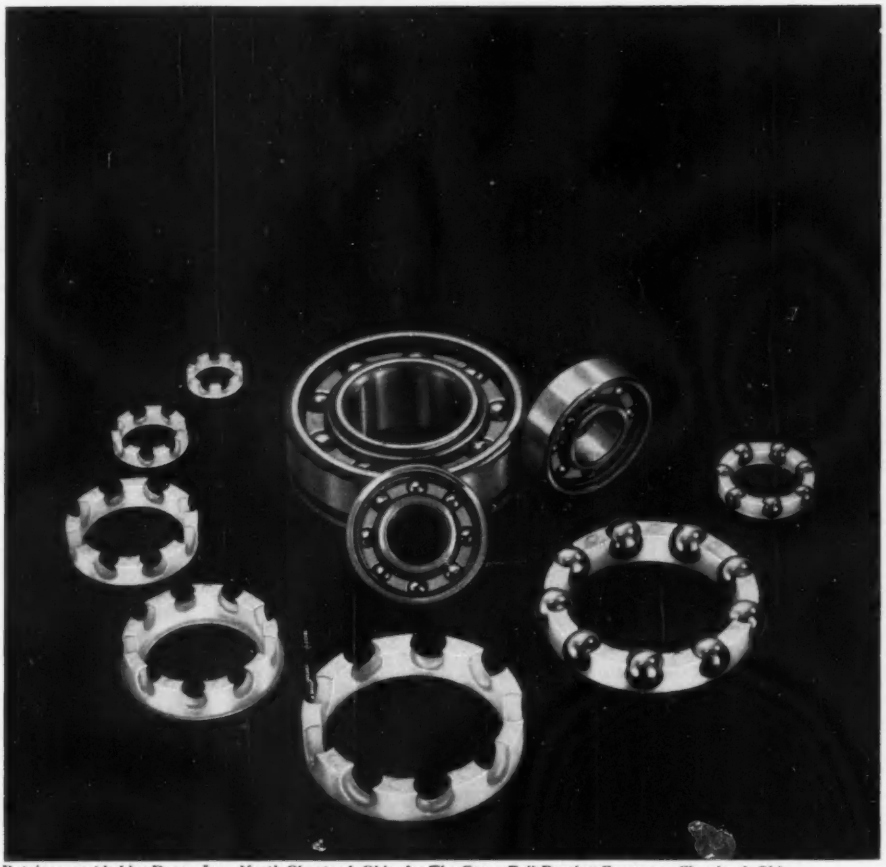
working with

Du Pont Zytel®

nylon resins

one of Du Pont's versatile engineering materials



Retainers molded by Dreco, Inc , North Olmstead, Ohio, for The Green Ball Bearing Company, Cleveland, Ohio.

How Du Pont ZYTEL® eliminates several difficult bearing problems

A new ball-bearing retainer, molded in one piece of Du Pont ZYTEL nylon resin, now eliminates several of the principal causes of premature bearing failure. Conventional retainers, fabricated from two halves of stamped steel riveted together, may fail because of burrs from the stamping, improper fits of the metal cups, rivet failure or lack of lubrication. And retainer wear may result in metal flakes that cause raceways to pit and then progressively break down.

None of those problems is encountered with one-piece retainers of ZYTEL. The material has no burrs to interfere with the operation of the bearing surfaces. The molded parts fit properly. Lubrication requirements are not critical. The high abrasion resistance of ZYTEL resins makes retainers wear as well as the hardened steel balls and raceways themselves. Finally, the sound-deadening qualities of ZYTEL eliminate noise due to retainer vibration.

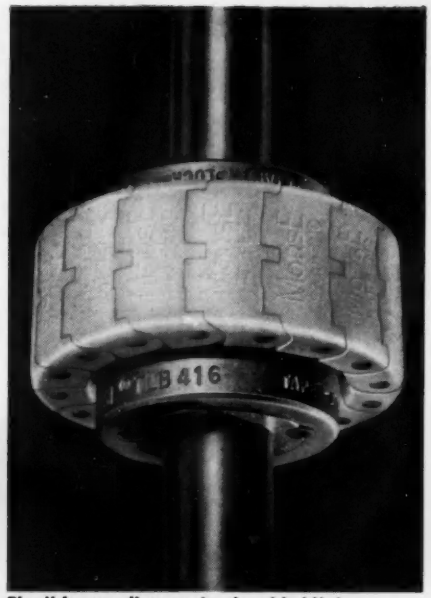
The unique design of these retainers takes advantage of several other properties of ZYTEL. The resiliency of these versatile resins, for example, permits ejection of the retainer from the spherical cores in molding.

From the standpoint of manufacture, the new retainers are assembled much more readily than metal retainers. They are installed by a simple snap fit. Net cost savings result because of higher output, more uniform product and reduced number of rejects.

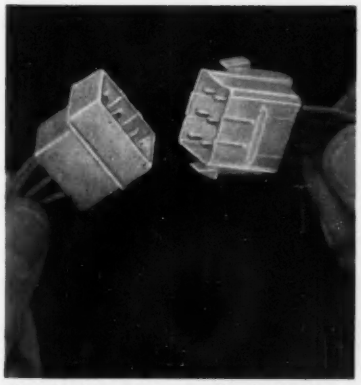
This is just one example of a component intelligently designed to take advantage of all the inherent properties of ZYTEL nylon resins. On the following page you will find more applications that may suggest ways in which ZYTEL can help *you* improve the design of automotive components.

tests at Ryan Aeronautical Co., San process, and exploration of possibilities

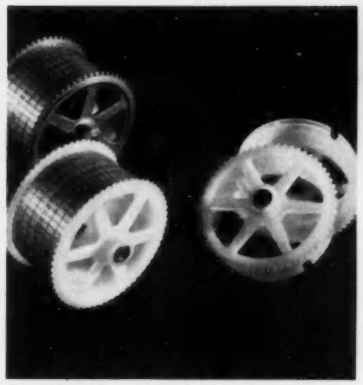
Mechanical, electrical properties of ZYTEL® make possible cost-saving automotive designs



Flexible coupling made of molded links of ZYTEL outlasts metal-chain coupling at least 6 to 1 and costs 20% less to buy and maintain, according to the manufacturer. Coupling is clean, quiet, corrosion-free. (Molded by Berea Plastics Company, Berea, Ohio, for Morse Chain Co., Ithaca, New York.)



Electrical connectors made with Du Pont ZYTEL depend on the high strength and good dielectric properties of the material. Reliable connectors speed assembly of automotive components... help assure long, trouble-free service. (Electrical connectors made by AMP Incorporated, Harrisburg, Pa.)



Sprocket for time clock illustrates the reduced costs and simplified assembly made possible by ZYTEL. This light injection-molded part has high strength and high fatigue-endurance limit. (Molded by Hamilton Plastics Molding Co., for the Cincinnati Time Recorder Co., both of Cincinnati, Ohio.)

The factors of superior performance, greater reliability, simplified design and reduced costs, which have led to the widespread use of ZYTEL nylon resins in a host of industrial and consumer products, are, of course, particularly important in the field of automotive design. Find out how you, too, may be able to incorporate economy in your design with improved quality. The coupon below will bring you useful design data and information on specific automotive applications of ZYTEL.

ZYTEL® *nylon resins*

one of Du Pont's versatile engineering materials

Alathon® polyethylene resins · **Delrin®** acetal resins · **Lucite®** acrylic resins

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Briefs of SAE PAPERS

continued from p. 123

Explosive Forming, F. A. COX, E. F. MELLINGER. Paper No. T39. Advantages of high energy forming of aircraft and missile sheet metal components; criteria used for selecting parts that lend themselves to this operation; tests at Ryan Aeronautical Co., San Diego, Calif., using dynamite, primacord, PETN sheet and gun powder as explosives show that unlimited pressures are obtainable by using one or combination of explosives, and metal movement of order of hundreds of feet per sec are possible; areas for future development.

Future Trends in Materials Removal Techniques, M. E. MERCHANT. Paper No. T40. Areas of high potential to be attacked in metal removal program include improvement of automation, tool materials, tool geometry, modification of work material properties in situ, improvements in grinding process, and exploration of possibilities of electrical electro-chemical electron beam and plasma-jet machining; general problem of energy use, e.g., physical, chemical, electrical, nuclear or other.

Theory and Application of Plasma Arc, R. M. GAGE. Paper No. T41. Principles of plasma arc torch; basic types are "transferred" arc torch for metal cutting and "non-transferred" type for plating processes; role of nozzle and nozzle material; applications in cutting of metals, etc; surface coatings can be deposited on almost any base material, including graphite, brass, steel, molybdenum, aluminum, and plastics; most important coating application is in use of tungsten to protect solid propellant graphite rocket nozzles.

ALSO AVAILABLE

1960 SAE AEROSPACE MANUFACTURING FORUM . . . SP-331 consists of reports on 4 panels, as follows:

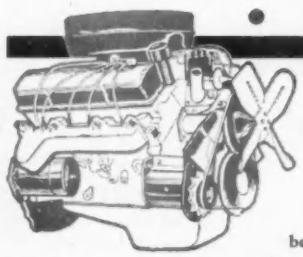
Engineered Manufacturing Management, reported by KAY MASTERS, secretary. Discusses need for management controlling manufacturing costs. Potential areas for savings are given.

Reliability — Organization and Achievement, reported by J. L. COBURN, secretary. Tells of Air Force-Industry approach to attaining a high degree of reliability on the B-58 weapon system. The reliability organizations of prime contractors and typical subcontractors, principal features of the reliability program, the mathematical reliability model, accumulation of failure rate data, and implementing reliability action by contractors is discussed.

How to Manage and Control Manufacturing Research, reported by F. H. WILLIAMS, secretary. The objectives of manufacturing research may be to develop new or revised designs, work out better processes, or devise new processes which will serve as a bridge to make future production possible. Because objectives vary as well as size of organizations, no one type of research organization will fit all industry, but in every instance a team operation is needed and the members of the team should represent every department involved. Discusses qualities desired in team members and factors controlling the selection of a project.

Facilities Planning and Introduction of New Products, reported by G. W. PERIMAN, secretary. Long range forecasting, capital equipment requirements, evaluation of projects, utilization of facilities including manpower and space, control and the audit of operations to aid in future planning. Consideration will be given to both defense and commercial projects, organization, introduction of new products and the part research and development should play in the planning of business activities.

JOHNSON *tappets*



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this new metal delivers unique performance

Sealed Power's stainless steel oil ring stops smoking in high compression engines—maintains its original, built-in tension.

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Stainless steel has no significant tension loss at engine operating temperature. This means the expander continues to exert the proper, predetermined pressure on the side rails. They, in turn, have the proper scraping action against cylinder walls far longer.

Other key features: proper cylinder wall conformability • quick seating • chrome-plated side rails for long life • easy assembly and installation.

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WHY BUY METAL YOU DON'T USE?

New Members Qualified

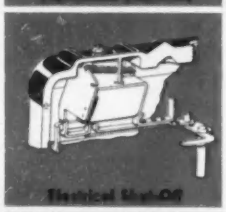
These applicants qualified for admission to the Society between May 10, 1960 and June 10, 1960. Grades of membership are: (M) Member; (A) Associate; (J) Junior.

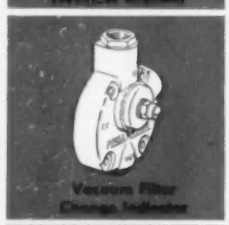
Atlanta Section: Arthur E. Flock, Jr. (M), John W. Hardison (M), B. Anthony Stevens (A).

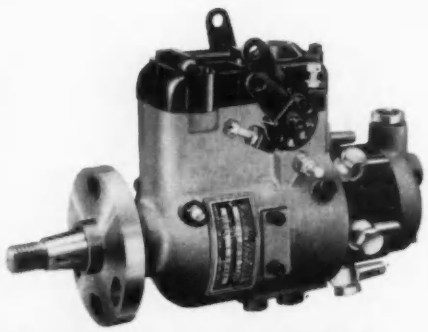
Buffalo Section: George Barboza (J), Donald Hermenet (M).

Central Illinois Section: Donald P. Cummins (J), Kenneth D. Diefendorf (J), Charles E. Phenix (A), Dale L. Shellenbaum (J), Warren D. Woodburn (A), Colin Ernest Woodley (J).

A few accessories that add versatility:







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Diesel engine manufacturers, their designers and engineers are specifying ROOSA MASTER because they know that it is the most versatile. There are many reasons for selecting this pump. Here are just a few:

- VERSATILE because of the variety of built-in, space saving, accessories demanded by modern diesel engine design. Roosa Master can provide more compact, lower cost, complete units to meet many different applications.
- VERSATILE because only one size pump serves either a 2, 3, 4, 6, or 8 cylinder, 2 or 4 cycle, small or large displacement engine . . . and only Roosa Master can be mounted vertically or horizontally.
- VERSATILE because it is applicable to automotive, construction, farm, generator, marine and stationary equipment guaranteeing dependable, economical service. Write for further information.

HMS ROOSA MASTER makes good diesels better

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DIVISION OF STANDARD SCREW COMPANY

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Cincinnati Section: N. V. Fischer (M), A. F. Schexnayder (M).

Cleveland Section: Russell DeYoung (M), C. Colmery Gibson (A), Walter E. Larkin (M), Kirk M. Reid, Jr. (M), Donald M. Satava (M), Marion L. Snedeker (M), Ronald Tyminski (J).

Colorado Group: Harry A. Lane (A).

Dayton Section: George F. Lawton (A), William E. Thomas (A).

Detroit Section: J. Louis Barribeau (A), Mehmet Kemal Bayburt (A), J. Richard Bohn, Jr. (A), Thomas R. Cassel (M), Robert G. Cassidy (M), Keith L. Cosner (M), William F. Darin (M), Kenneth Irving Goedert (A), Duane H. Goodsmith (A), Malcoln C. Goodwin (J), Herbert L. Gordon (M), Joseph R. Harris (M), Donald P. Haseltine (A), Alton J. Hole (M), Earl M. Hunter (M), Marvin William Jackson (M), Thomas L. Ketten, Sr. (A), Leslie Hamilton Klauer (M), Morris Kosten (M), Carl Lessen (M), Seymour A. Lippmann (M), John D. McBrian (M), Ronald M. McIndoe (M), Robert E. McMaken (J), James S. Owens (M), Guy Donald Pierce (M), John W. Polick (A), Robert Allen Potter, Jr. (J), Tom Rasmussen (J), Robert Fullington Rea (M), Garth R. Sayes (M), Robert J. Sitler (A), Eugene Vincent Spanski (M), Ivan M. Swatman (M), C. Arthur Van Dell (M).

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Mid-Continent Section: Donald A. Amann (M).

Mid-Michigan Section: Winthrop Gerald Beach (M), T. R. Fernand (M), Darwin A. Mixer (M), Cecil R. Peterson (J), Thomas G. Toeppner (M).

continued on p. 130

WHY BUY METAL YOU DON'T USE?

Switch to Allegheny Ludlum Cast-to-Shape Tools

FORGED DISC

Forged disc necessary for fabricating welded tube mill roll.

CAST-TO-SHAPE TOOL STEEL

Cast-to-shape welded tube mill roll. 220 lbs. lighter than forging; $780 cheaper for finished shape.

$780 Saved by changing to Cast-to-Shape

Why pay for metal that ends up chips on your floor? Here are two pertinent reasons why you should stop hogging your complex tools from blocks of metal and let Allegheny Ludlum cast them to shape.

CAST-TO-SHAPE MEANS YOU BUY FEWER POUNDS OF METAL.
For example, the roll shown above is 220 pounds *lighter* in the rough state than its forging cousin. Allegheny Ludlum cast-to-shape tools are more economical than tool steel forgings, *and* just as strong in certain applications.

CAST-TO-SHAPE MEANS LESS FINISH MACHINING.
This is especially important with a complex shape. For instance, the casting above has only ¼ to ⅜ inches of machine stock on its surfaces, requiring only one roughing and one finishing operation. Estimated savings by using an Allegheny Ludlum cast-to-shape tool amount to $780.

7271

Allegheny Ludlum, a tool steel producer who makes cast-to-shape tools, casts them with the same precise quality control for which their tool steels is known. A full line of cast-to-shape tool steel grades is available. You'll find ones with high resistance to abrasion, compressive strengths of approximately 400,000 psi, easy machinability, hardening with almost no distortion, toughness, high red hardness, and the capacity to take a high polish.

Find out now how you can cut costs on your complex tools. Write for FC-4, a 28-page technical discussion of A-L's Forging and Casting Division with applications, pattern information, design tips, analyses, and heat treating instructions. Or call your nearest A-L tool steel warehouse or distributor.

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Thanks to non-metallic seals, the new Stratoflex all-purpose couplings guarantee a positive self-sealing unit when connected or disconnected. When the two halves are connected, the valves open automatically to assure maximum flow, with a minimum of pressure drop.

Stratoflex Self-Sealing Couplings are available in three designs: wing nut, hex nut and knurl sleeve, with NPTF Pipe Thread or SAE "O"-Ring Boss Thread, in sizes ranging from ¼" to 1¼".

Stratoflex Quick-Disconnect Couplings are furnished in NPTF Pipe Thread and SAE "O"-Ring Boss Thread, with a size range from ¼" to 1".

For complete information on Stratoflex Hydraulic Couplings, write for Stratoflex Bulletin S-6 immediately.

SF8-9

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Toronto, Tulsa

New Members Qualified

continued from p. 128

Milwaukee Section: James A. Meyer (M), Richard Carl Mortensen (M), C. R. Rigby (M).

Mohawk-Hudson Section: Earl G. Smith (A).

Montreal Section: John H. Blueth (M).

New England Section: 2nd Lt. Charles G. Simpson (J), Adrian E. Van Dorpe (A).

Northern California Section: Glen H. Boyd (M), Richard M. Dawson (M), Jack T. Guerin (M), Donald W. Halfhill (M), Walter H. Westerback (M).

Northwest Section: William E. Dennis (M).

Ontario Section: John V. Berger (J), Robert G. Brown (A), Kenneth R. Coulter (M), Franklin H. Cressman (M), G. L. Felix (M), Lorne F. Hiller (A), D. B. McColm (M), Andrew Millar (M), William George Sadler (A), Alex Shelegey (M), E. N. Weldon (M).

Philadelphia Section: John B. Darrah (M), James F. Light (J), Albert Cooper Littlejohn (A), John F. Pfeffer (A), William H. Reinhold, Jr. (M), Jerry D. Shaw (M).

Pittsburgh Section: Lewis Z. Carey (A), Thomas F. Hanlon (A).

Rockford-Beloit Section: Rudolph C. Kozlik (M), Harold A. Weiss (M).

St. Louis Section: Robert Pahl (J).

Southern California Section: John Burt (A), Donald L. Meehan (M), William L. Rose (A), Edward G. Rowlett (M).

Southern New England Section: James M. Sullivan (M), Robert T. Sullivan (A).

Syracuse Section: Theron R. Chamberlain (M).

Texas Section: Tom J. Sheffield (A).

Texas Gulf Coast Section: James A. Embry (M).

Twin City Section: John William Barlass (J), Thomas C. Brown (A), Brent T. Harding (A), Harijs J. Saukants (A).

Virginia Section: Walter Royal (A).

Washington Section: David A. Didion (J), Clifford Horton May (M), John W. Sawyer (M).

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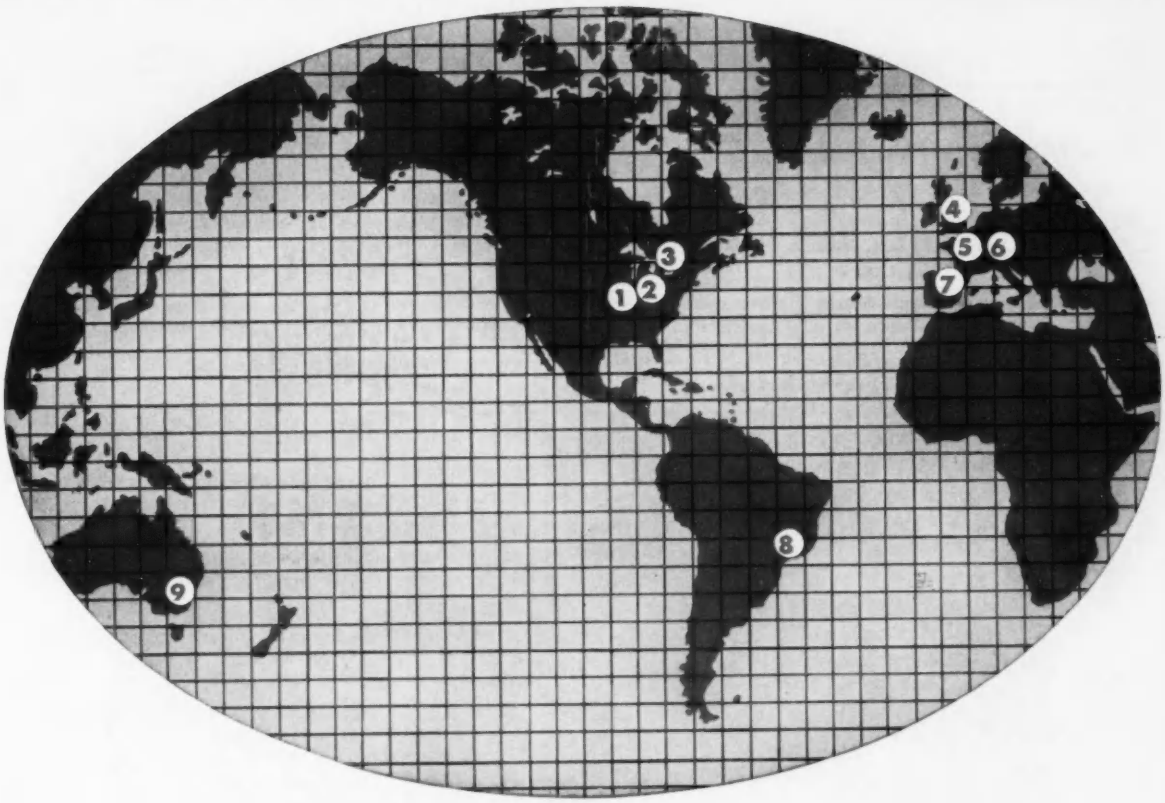

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Gemmer Division • Detroit

New Members Qualified

continued from p. 130

Western Michigan Section: James F. Kolbe (J), Frank G. Warrick (M).

Williamsport Group: Cornelius H. Buddenbaum (M).

Outside Section Territory: Charles Leslie Callum (M), 1/Lt. Daniel B. Geran (J), D. E. Ricketts (A), George Sklar (M), Roger W. Williams (M).

Foreign: Donald Henry Ballard (M), England; Alessandro E. Carelli (M), Italy; Dr. Cesare Cecchini (M), Italy; P. G. Kumar (J), India; Hans Mersheimer (M), Germany; Oscar V. Navarro (M), Argentina; George Philippe Russbach (M), France; Donald Sainsbury Smith (M), England; T. Sornam (J), India; S. Vaidheeswaran (J), India.

A
make a tough job easy
Ask Allen to design, engineer and fabricate a cab "to match your machine"
Our diversified cab experience assures you of maximum safety, smart styling, effortless visibility and operator convenience at reasonable cost.
Ask for more information or a personal discussion of your project — there's no obligation.
ALLEN INDUSTRIAL PRODUCTS, INC.
Affiliate of Stelper Steel Products Corporation
318 Pilgrim Road • Menomonee Falls, Wisconsin
Allen

Applications Received

The applications for membership received between May 10, 1960 and June 10, 1960 are listed below.

Alberta Group: Robert James Clark, William A. G. Everett, Curt A. C. Pedersen

Atlanta Section: John McNulty Horne, Parker Little, Loyl R. Thomas

Baltimore Section: Rogar Lawrence Odette

British Columbia Section: William Peter Inge

Buffalo Section: Frank R. Cowan, Joseph Anthony Grom

Central Illinois Section: Richard P. Larence, Marion J. Witzenburg

Chicago Section: James Robert Clarke, William Harrison Fetridge, George W. Folland, Ugo G. Frisoni, James Donald Harris, Richard K. Hedlund, William C. Keeran, Joseph L. King, Franklyn J. Lammers, Charles B. Tracy

Cincinnati Section: John R. Savage

Cleveland Section: Clifford L. DeShelter, James A. Krause

Colorado Group: William E. Adcock

Dayton Section: Bert Paul Griffith, Chris Fred Keller, Jr., Zane R. Oaks, Gerald M. Sturm

Detroit Section: Ahmet Recai Akman, Karl Douglas Burdick, James H. Currie, Leo R. Dixon, Arthur W. Dulemba, Harry H. Fetters, Alan Robert Fisher, Lawrence H. Gillespie, Jr., Fritz E. Goettner, John P. Gorys, R. E. Hergenroether, James Francis Horgan, Leonard Gustave Johnson, Joseph Langlois Knapp, Karl Norman Krecke, Howard M. Martinie, Vacys Z. Mitkus, Harold A. Moore, Jr., Robert Earl Neth, Harry T. O'Connor, Russell DeWitt O'Neal, Robert F. Pecha, John J. Pollock, John Popovich, Norman Douglas Rice, Gilbert R. Richards, Bernard E. Sanders, Edmund F. Sarosy, James F. Schmitt, Samuel Herbert Schram, Charles E. Sloan, Jerome T. Smutek, Arthur J. Stock, John E. Sullivan, Richard Harry Tarske, Frank George Tenkel, Jack Lee Thon, David N. Viger,

continued on p. 136

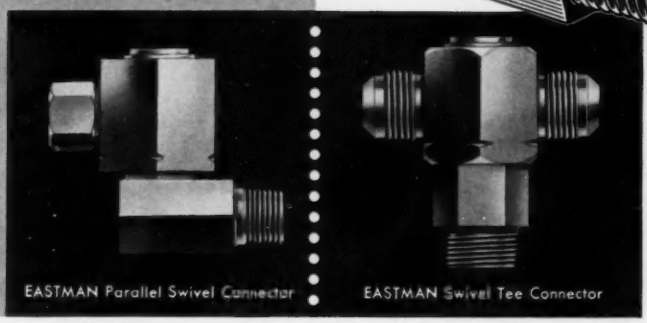
Eastman

improves INDUSTRIAL SWIVEL CONNECTOR

Licensed Under
Pat. No. 2481404

AMAZING VERSATILITY AND ADAPTABILITY!

These two adaptations, specified by two of America's largest major equipment manufacturers, reveal the unique adaptability and versatility of EASTMAN'S improved Industrial Swivel Connector.



EASTMAN Parallel Swivel Connector

EASTMAN Swivel Tee Connector

improves **SEALING QUALITY**
through use of SIX seals, thereby eliminating failure from grit, dust and other foreign materials.

improves **SERVICE LIFE**
through new design and engineering, the interior is chrome-hardened with a highly polished mirror finish.

improves **UNIFORMITY OF FLOW**
at any angle of the swivel by undercutting the shaft to equal diameter of the orifice.

improves **SERVICEABILITY**
through shorter, more compact housing; saving weight. Hex design permits multiple tapping on housing; easier assembly.

While the use of EASTMAN'S High Pressure Industrial Swivel Connector eliminated the cause of hose failure due to constant, extreme flexing, it tended to increase the load on the swivel connector.

To improve the performance of the swivel itself, EASTMAN engineers improved its internal design, chrome-hardened its interior surfaces, cadmium plated the shaft and then machined them to a mirror-like finish.

Satisfactory service under the most unfavorable field conditions was insured by increasing sealing rings from four to SIX: 2 leather dust seals, 2 synthetic back-up washers and 2 quad rings of oil-resistant rubber (−65° to +250°).

Exhaustive tests at 3000 p.s.i., through one million cycles, with the hydraulic fluid *saturated* with abrasives, dirt and other foreign materials, proved EASTMAN'S Industrial Swivel Connector satisfactory in every respect and did not cause failure of any kind.

That is why America's leading OEM's and replacement buyers specify *complete* EASTMAN Hydraulic Hose Assemblies . . . for improved design, quality manufacturing and exhaustive testing. It pays to specify EASTMAN.

STANDARD SIZES AND COMBINATIONS AVAILABLE

LOW TORQUE—Freedom from friction, even under high pressure.

WIDE RANGE—Operating pressures up to 5000 p.s.i. trouble-free operation through wide temperature range (−65° to +250°).

ROTATION—Full 360° for all manifolds.

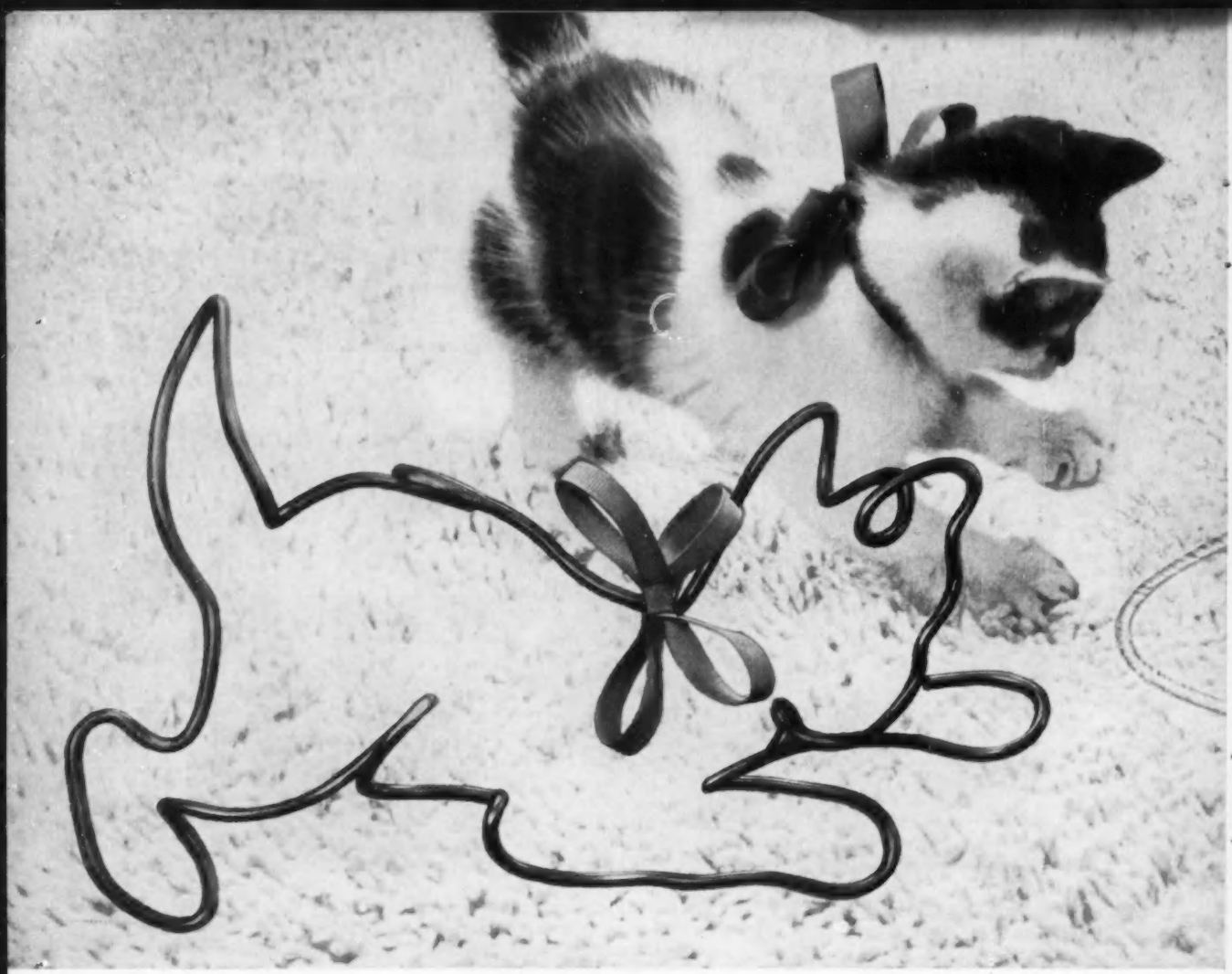
SIZES—Steel, plated for corrosion protection—½", ¾", 1", 1¼".

Other sizes available on request.

LOOK INTO EASTMAN'S IMPROVED SWIVEL CONNECTOR—WRITE TODAY!

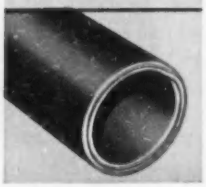
Please send me Bulletins 100 and 200 on low, medium and high pressure assemblies.

Eastman MANUFACTURING COMPANY
DEPT. SAE-7, MANITOWOC, WISCONSIN



There's almost no limit to the things Bundy can mass-fabricate

Bundyweld is the original tubing double-walled from a single copper-plated *steel* strip, metallurgically bonded through 360° of wall contact for amazing strength, versatility.



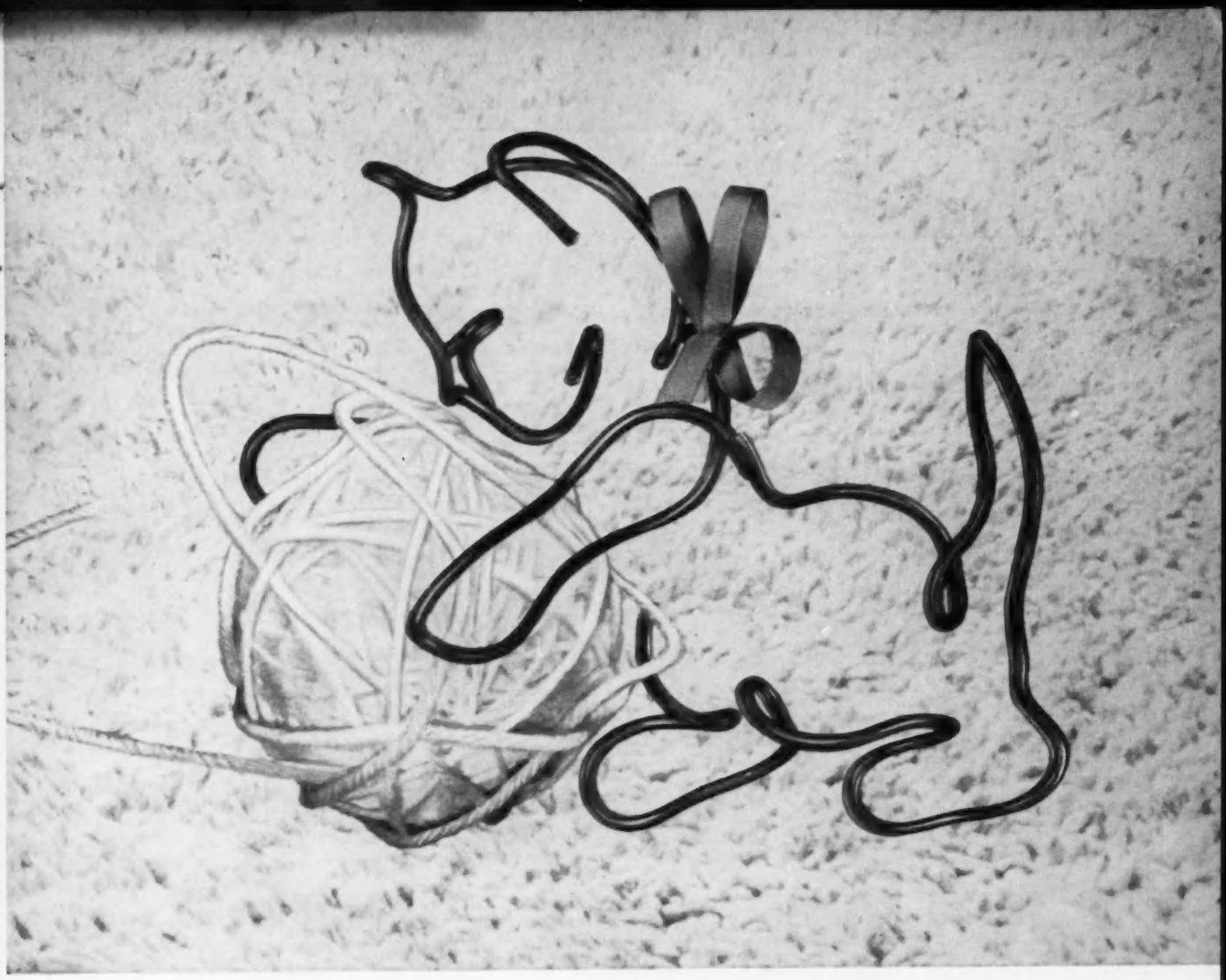
Bundyweld is lightweight, uniformly smooth, easily fabricated. It's remarkably resistant to vibration fatigue; has unusually high bursting strength. Sizes up to ⅝" O.D.

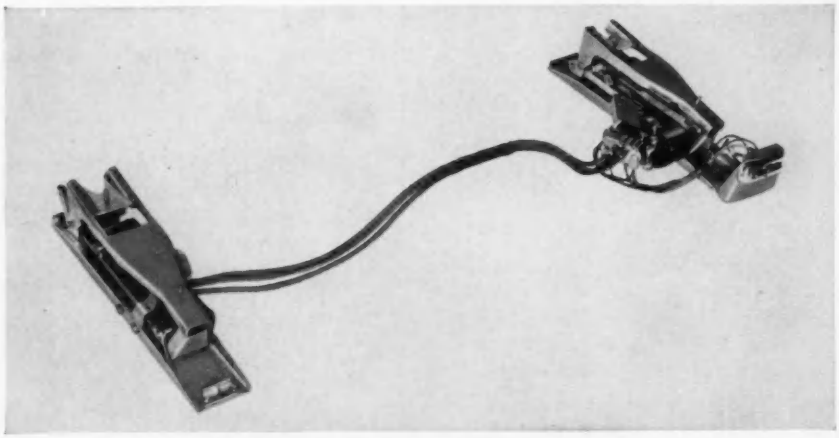
Experience makes the difference! And Bundy engineers, backed by years of experience in designing and fabricating tubing parts, can help you solve your tubing problem.

Bundy engineers will work with you at any time during the development of your product. They may be able to suggest design modifications in your tubing components to cut fabrication costs. Then your design will be turned over to Bundy specialists who will mass-fabricate your tubing parts at low unit cost with Bundyweld®.

Bundyweld is the original steel tubing that's ***double-walled*** from a single steel strip for extra strength and resistance to vibration fatigue. It's the safety standard of the automotive industry. Bundyweld is covered by Government Spec. MIL-T-3520, Type III.

Got a tubing problem? Bring it to Bundy. Call, write, or wire: Bundy Tubing Company, Detroit 14, Michigan.





Six lengths of Bundyweld tubing are used as torque tubes to guide and protect the flexible cables that drive the slave units in this power seat unit. The tubes need to be extremely smooth in order to protect the cables from fraying . . . and they have to be easily fabricated and economical, too. Bundyweld tubing meets every requirement!

There's no substitute for the original

BUNDYWELD® TUBING

WORLD'S LARGEST PRODUCER OF SMALL-DIAMETER TUBING • AFFILIATED PLANTS IN AUSTRALIA, BRAZIL, ENGLAND, FRANCE, GERMANY, AND ITALY

BUNDY TUBING COMPANY • DETROIT 14, MICH. • WINCHESTER, KY. • HOMETOWN, PA.

to ⅝" O.D.

Bundy Tubing Company, Detroit 14, Michigan.

Applications Received

continued from p. 132

Jon Stephen Wilson

Hawaii Section: Tatsuo Nakashima

Indiana Section: Frederic Rigdon Bartlett

Kansas City Section: Boyd L. Freels, Charles R. Hayes, John H. Works

Metropolitan Section: Charles H. Beckham, Brett P. deDube, Rene' B. Eppi, Marcy B. Fannon, Northrop Rogers Fletcher, Gerhard K. Pilz, Daniel Poryles, William Joseph Powers, Kevin Sheehan, Gilbert Zweig

Mid-Michigan Section: Charles E. Drury, Bernard J. King, Jr., William B. Larson

Milwaukee Section: Ray Dean Beard, Samuel Francis Gray, P. J. Rossiello, Edmund Rostkowski

Montreal Section: Ian Butter

Northern California Section: Phillip Alvin Bohm, Melvin C. Holdorf, Louis Stanley Korfhage, Daniel James Maneely, Walter Jakob Spielberger, Edwin G. Tandberg

Northwest Section: John Arvid Holmberg

Ontario Section: Harry A. J. Atkins, Jr., William E. Austin, James R. Baxter, William C. Chisholm, Bruce C. Fouse, John F. Hand, Joseph Anthony Kemp, Archie K. Ledingham, Ian Mackenzie McLean

Oregon Section: Franklyn O. Gieseke

Philadelphia Section: J. B. Curcio, W. Roderick Hunsworth, John Anthony Marino, Dineshchandra S. Shah

Pittsburgh Section: James W. Butler, Jr., Joe Earl Taucher

Rockford-Beloit Section: Darold Dean Russell, Robert Hilton Shoquist, Romas Balys Spokas

St. Louis Section: Franklin D. Maddox, Joseph Patrick Mulligan

Salt Lake Group: Charles Edward Wiemers

Southern California Section: Harry T. Linde, Bernard J. Sadoff, Jr., Roy V. Spangler, Daniel G. Woodhouse

Southern New England Section: Ralph L. Kalp

Texas Gulf Coast Section: Boris K. V. Danielowsky, Don H. Morrison

Twin City Section: Fred C. de Castro

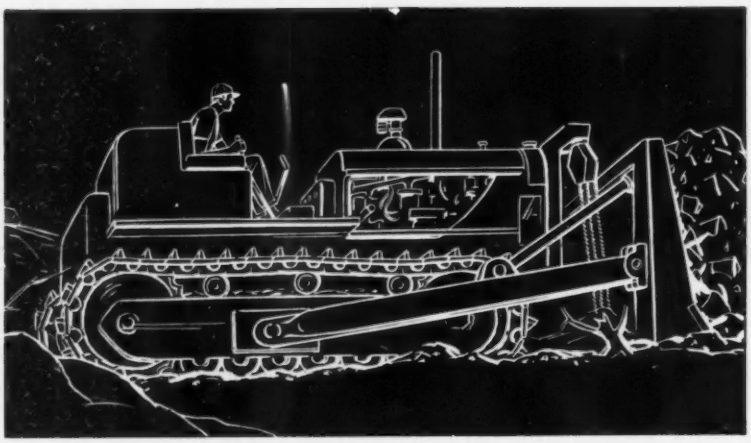
Washington Section: Ivar C. Peterson, Joseph P. Smith, Jr.

Western Michigan Section: Jack Ernest Larson

Williamsport Group: Ralph E. Thomas

Outside Section Territory: Dale Francis Buller, Weldon Leon Phelps, Roger Frank Ort, Lyle Dean Six, James D. Wormley

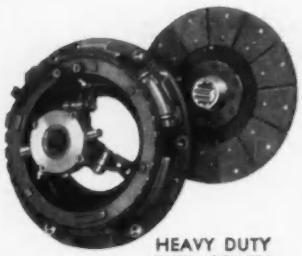
Foreign: Eric H. Bowers, England; Allert Jan Buijs, Holland, Willem Fredrik DeVries, Holland; OM Narian Mehrotra, India; Hardarshan Singh Mejie, India; Nalin H. Shah, India; Yutaka Shirai, Japan; Ira Griffin Svendsgaard, Philippines; Carlos A. Weil, Argentina



BETTER COMPONENTS...
BETTER PRODUCTS!

Cooperation produces the final design

When each component part is the best, the whole machine is right. Rockford Over-Center Clutches are the finest made for crawlers, cranes and other heavy-duty equipment. If your equipment is in the design stage, let Rockford Clutch engineers help you select the best clutch. Rockford Clutches in standard sizes suit almost every need. Custom models can be designed for your applications. Call or write for the Rockford Clutch Catalog.



HEAVY DUTY OVER CENTER CLUTCHES

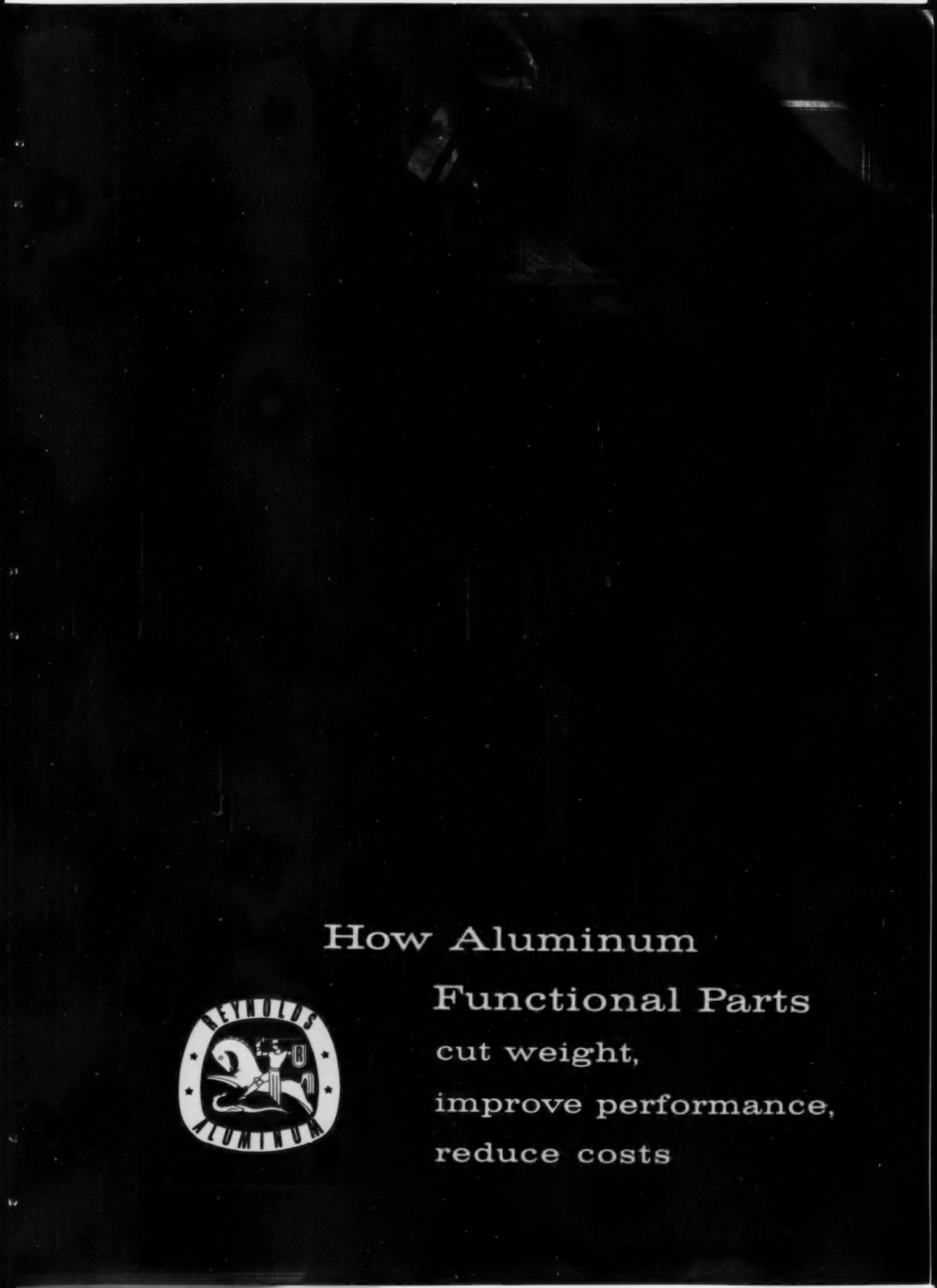
ROCKFORD CLUTCHES

ROCKFORD CLUTCH DIVISION BORG-WARNER

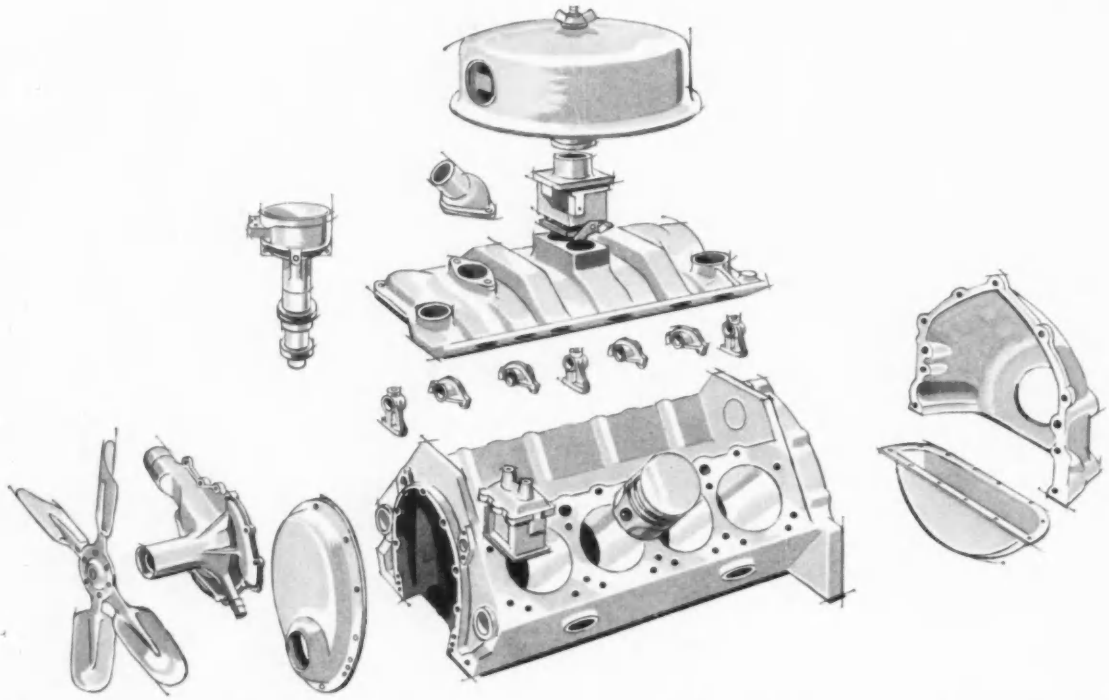
316 CATHERINE ST. ROCKFORD, ILLINOIS

Export Sales Borg-Warner International 36 So. Wabash, Chicago, Ill.

BUNDY TUBING COMPANY • DETROIT 14, MICH. • WINCHESTER, KY. • HOMETOWN, PA.



After 21 years of continuous growth and diversification as Bendix Aviation Corporation



The more than forty different functional parts made with aluminum in the fine 1960 automobiles add up to millions of individual aluminum parts—and there are good reasons for this substantial figure.

The main reason is the increased emphasis on weight reduction, the prime target in compact car engineering and an important objective in the engineering of *all* automobiles. *Lightweight aluminum is the best solution to weight control.* Another key factor in aluminum's growing usage is new processing techniques that result in a *better part at a lower final cost.* Other aluminum advantages such as corrosion-resistance, strength, and high thermal and electrical conductivity are also important in various applications.

One or more of these aluminum advantages is being put to good use in the representative functional parts illustrated in this advertisement. For example, aluminum's lightness in intake manifolds reduces front end weight, improves handling and weight-horsepower ratio. In the same part, aluminum's high thermal conductivity is of benefit, for example, in manifold probes which transfer exhaust gas heat to the intake manifold to preheat the incoming mixture. Aluminum's high thermal conductivity also helps in carburetor mounting pads through which water from the cooling system is circulated, acting to heat the carburetor and eliminate icing.

Another key advantage of aluminum is the fact that it lends itself to ideal "integration" of physical properties and part function, eliminating assembly components and increasing efficiency of performance. For example, in rocker arms and supports, aluminum's high strength to weight ratio combines with die cast designs to take advantage of high production casting techniques with resultant lower cost. The intake manifold and carburetor mounting pad take advantage of aluminum's thermal conductivity, light weight and castability, reducing the number of parts.

These weight and physical benefits combined with production advantages are also important in fuel, oil and water pump components, clutch housings, pistons, carburetor bodies, distributor bases, horn parts, generator end frames and support brackets and many other parts.

Because of aluminum's proved advantages in so many parts, *radiators, alternator and DC generator housings, mufflers, battery straps* and other parts are receiving close design and engineering attention to take advantage of aluminum's light weight and savings in tooling and assembly costs.

For information and assistance on aluminum automotive applications, talk to a Reynolds Aluminum Specialist. Write or phone *Reynolds Metals Company, P.O. Box 5050, Seven Oaks Station, Detroit 35, KEnwood 7-5000. Or contact your nearest Reynolds office or write P.O. Box 2346-MX, Richmond 18, Virginia.*

NOTE: Before you buy any part—have it designed and priced in aluminum. Basic material costs do not determine part costs. New techniques and processes—applicable only to aluminum—can give you a better product at a lower final cost.

REYNOLDS ALUMINUM

the metal for *automation*

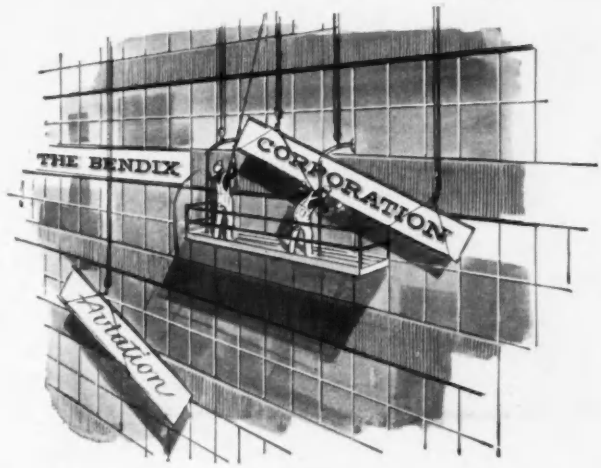
TRADE MARK

Watch Reynolds TV shows: "BOURBON STREET BEAT" "ADVENTURES IN PARADISE"; and "ALL STAR GOLF" (resuming in October)—ABC-TV

After 31 years of continuous growth and diversification as Bendix Aviation Corporation . . .

We've changed our name to

The Bendix Corporation



To reflect our dynamic growth in such fields as electronics, missiles and space, automotive, weapons systems, computers, machine tools, instrumentation, nuclear technology, hydraulics, meteorology, electrical, marine and others, we dropped "Aviation" from our corporate name on June 1, 1960. We do not wish to convey the impression that our products and skills are limited to the aviation field alone, although aviation products accounted for billings of $388,700,000 in 1959.

Today Bendix®—through 25 divisions and 16 subsidiary and affiliate companies around the world—serves many fields.

Our success in the rapidly expanding age of aviation has long obscured the fact that the Bendix automobile starter drive was the company's first major product. Bendix introduced the type of four-wheel brakes that over the years has been used on most makes of cars. Bendix also pioneered automotive power brakes and power steering. Our automotive business in 1959 totaled $114,300,000.

A notable trend in Bendix' recent history is the utilization of electronics in many of our major fields of activity. These range from automobile radios to aircraft and industrial communications and automatic flight controls . . . from electronic computers and data processing to numerical tape control systems for machine tools . . . and from transistors and ship-to-shore telephones to sonic cleaning and undersea sonar detection equipment. Approximately 40% of Bendix products are electronic, including air defense radar which today guards 25 million square miles.

Missile and space equipment accounted for $103,000,000 of our total business of $689,692,312 in 1959. In addition to being the prime contractor for two important missiles, Talos and Eagle, we are also a supplier of components and sub-systems for most U. S. missiles. Bendix is likewise taking an active part in Project Mercury and in satellite communications. The first is the program to put a man into space. The second will mark a new era in communications by using a satellite in orbit as a relay station for global radio messages.

Bendix also has a growing and diversified nuclear program. Since 1949 we have operated the Kansas City Division for the Atomic Energy Commission. It is a large manufacturing organization employing 7,500 people engaged in the atomic weapons program. We also supplied control mechanisms for nuclear submarines and nuclear industrial power plants, and we are playing a part in developing the newest U. S. atomic power plants for aircraft, missiles and space vehicles.

Thus, as we drop "Aviation" from our corporate name, but not from our programs, we face a tomorrow where the range of our opportunities is broadening at a breathtaking rate.

A thousand **THE Bendix CORPORATION** Fisher Bldg., Detroit 2, Mich. *diversified products*

Naugatuck KRALASTIC®

New FIAT uses 12 pounds of **KRALASTIC!**

What makes one of the world's leading auto makers turn to KRALASTIC for his new top models? Why are the windshield and window trim, steering-wheel housing and entire dashboard of every new FIAT 2100 and 1800 made of this unique rubber-resin? The answer lies in the material itself.

KRALASTIC's clear-through color eliminates costly finishing operations and at the same time ends fear of unsightly scratching in use. Unlike metals, KRALASTIC never feels cold or clammy to the touch, will never rust, rot or corrode. KRALASTIC weighs less than aluminum. KRALASTIC is easily molded to practically any desired shape or form. KRALASTIC has a self-lubricating quality that helps to eliminate "inevitable" squeaks and rattles. And finally, KRALASTIC provides a combination of toughness and dimensional stability that is unsurpassed.

How about your newest, proudest product? Does it enjoy the kind of manufacturing and selling advantages KRALASTIC has already given such varied products as baby combs and water-well pipe? Learn more about this exceptional plastic material now.

US RUBBER

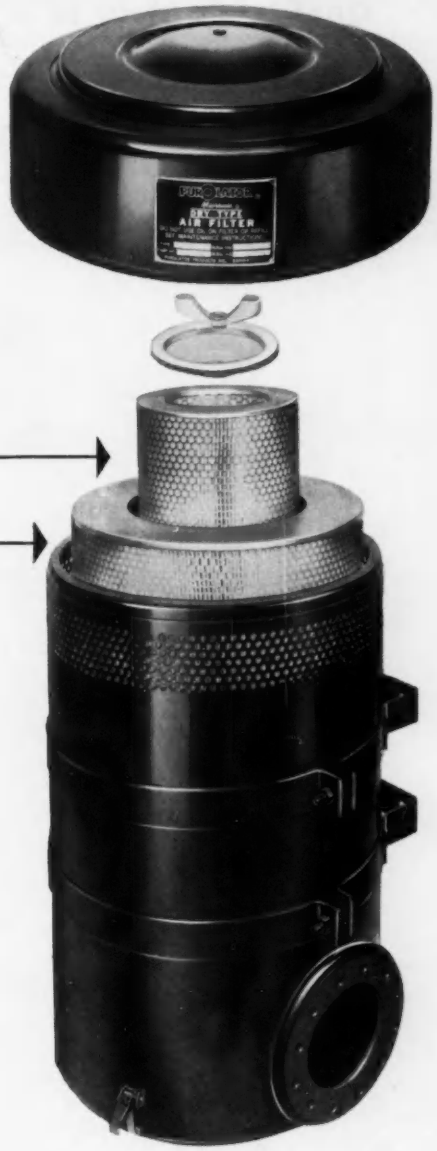
United States Rubber

Naugatuck Chemical Division

728K ELM STREET
NAUGATUCK, CONNECTICUT

KRALASTIC RUBBER-RESINS • **MARVINOL** VINYLS • **VIBRIN** POLYESTERS

Akron · Boston · Chicago · Gastonia · Los Angeles · Memphis · New York · Phila. · CANADA: Naugatuck Chemicals · Elmira, Ont. · Cable: Rubexport, N.Y.



an element here

and an element here

assures 99.98% filtration efficiency even when 1 element is out of operation

IT'S THE NEW PUROLATOR TWO-STAGE FILTER

Simplicity of design makes the first cost of Purolator's new dry-type two-stage filter as low as any two-stage filter on the market. Each element filters independently, and together they dustproof your engine as no other filter can . . . 99.98% efficient.

Users save money and get better engine protection from this new Purolator filter, too. The first stage element will last up to 2000 hours, depending on operating conditions. The second stage will usually last almost indefinitely if the first element and sealing gaskets are maintained properly.

Another big user-advantage is the way the two-stage design protects the engine despite accidental mishandling of the element. Even if the first stage element is damaged, the chance of harming the engine can be discounted when it is protected with the second stage back stop element. In addition, the second stage element lets the operator service the unit in the field, regardless of how dusty the conditions are.

Both elements filter uniformly, in depth, over their whole surface, because they're both precision made of plastic impregnated cellulose. This series of two-stage filters is rated from 450 to 1150 cfm, with exceptionally low initial restriction. Mounting straps, rainhoods and outlet adapters are available.

For more information write to Purolator Products, Inc., Department 3896, Rahway, New Jersey.

Purolator Products, Inc.
Dept. 3896, Rahway, New Jersey

Please send me complete data on the new Purolator two-stage filter series.

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

Filtration For Every Known Fluid

PUROLATOR

PRODUCTS, INC.

RAHWAY, NEW JERSEY AND TORONTO, CANADA

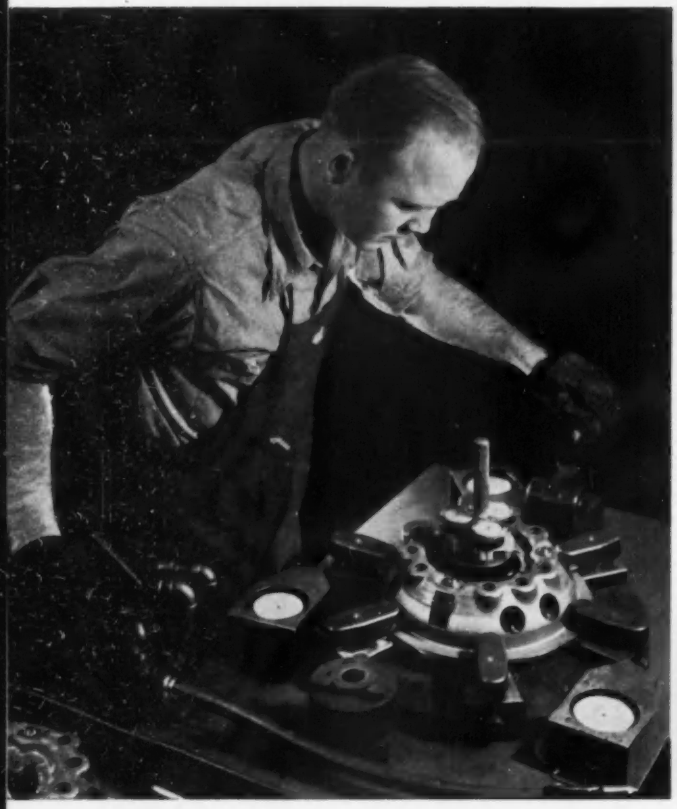
Quality Control is a BORG & BECK tradition that means

BETTER CLUTCHES

At Borg & Beck, quality control is not just a phrase to which we pay lip service. It is a tradition born of the long-standing Borg & Beck policy of building up to a standard —not down to a price.

In the photograph at the left, for example, release levers are being checked on special equipment to make sure they are parallel with the pressure plate. As shown at the right, every Borg & Beck clutch plate is carefully tested for correct deflection to assure positive release. And every driven plate and cover assembly is dynamically balanced for maximum smoothness of operation.

These exacting tests are typical of the extra care that goes into every step in the making of Borg & Beck clutches. They are your assurance of top quality, top performance, top value. And that means: BETTER CLUTCHES.



BORG & BECK CLUTCH · THE STANDARD · Reg. U.S. Pat. Off.

BORG & BECK · B-W · BORG-WARNER

BORG & BECK®

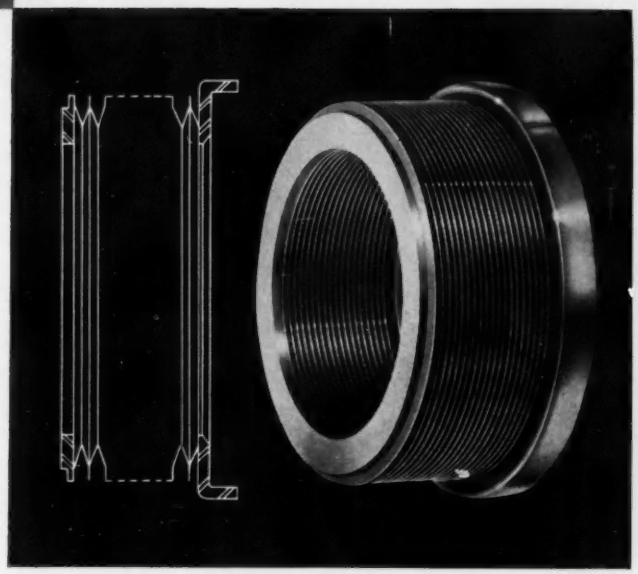
THE AUTOMOTIVE STANDARD FOR MORE THAN 40 YEARS

BORG & BECK DIVISION, BORG-WARNER CORPORATION, CHICAGO 38, ILLINOIS

Export Sales: Borg-Warner International, 36 S. Wabash, Chicago 3

C/R DESIGN NOTES

How C/R's New Metal Bellows Seal Meets Seemingly Impossible Operating Conditions



Operating Ranges

Temperature	−400° to 1000° F.
Pressure	500 psi
R.P.M.	80,000 plus

These known operating ranges indicate the function of this seal. It is designed for applications where temperatures and mediums to be sealed forbid the use of any organic materials. Typically, these applications include fuel pumps, compressor power units and turbine starters characteristic in rockets and missiles. Other applications include mechanisms which are exposed to a high level of radioactivity.

Design Advantages

The C/R metal bellows seal consists of a metal bellows — a welded homogeneous unit which is secured at one end — and a carrier ring in which the sealing face is mounted. The seal does not contact the shaft. It is stationary, and the only rubbing surfaces are the sealing face and mating ring. These surfaces are precision lapped to provide a positive seal with minimum friction. At any given pressure, the seal can be designed to maintain proper and constantly effective face loads. It orients immediately to run-out and will resist any torques it is subjected to in operation. The design has high end-play tolerance: Chicago Rawhide engineers have deflected a bellows .100 in. for three million cycles at 1750 cpm and at a temperature of 500° F. with no adverse effects.

A further advantage is relatively light weight and compactness. The C/R metal bellows seal can be designed for minimum axial and radial space. Axially, complete seals can be produced within a ¼ in. cross-section. Radially, dimensions are comparable with conventional end face seals.

The C/R metal bellows seal can also be designed with an extremely low coefficient of expansion. The importance of this factor becomes apparent with the fact that in many applications the operating temperature may change hundreds of degrees in a very few seconds.

Mediums To Be Sealed

Virtually any known liquid or gas may be positively sealed with this design, depending upon duration or service life. From a practical viewpoint, the C/R metal bellows seal is the best design for the sealing of cryogenic and high-energy fuels such as LOX, hydrogen peroxide, fluorine and other missile and rocket propellants.

Where possible, lubrication of the two sealing faces is desirable to prolong service life. However, the medium being sealed commonly acts as the lubricant and may be merely hot gas.

Materials

Sealing faces and mating rings for the C/R metal bellows seal are available in a variety of materials including carbons, carbides, ceramics and various alloyed metals for both high temperature and corrosion resistance. The bellows can be furnished in any of several metals and alloys such as stainless steel, Monel, Inconel X, Ni-Span C and other special alloy steels.

Consult C/R Engineers

Each application for the C/R metal bellows seal is essentially a custom-design and an intimate knowledge of all conditions to be encountered must be known by Chicago Rawhide engineers to produce the correct combination of properties in the seal. Then, whether you require five, fifty or five thousand seals, Chicago Rawhide will design and produce the correct seal to solve your problem.

Helpful Design Data:

We will gladly furnish you with a design guide and space envelope data concerning the C/R Metal Bellows Seal. Just write for Bulletin MBS-1 on your company letterhead.

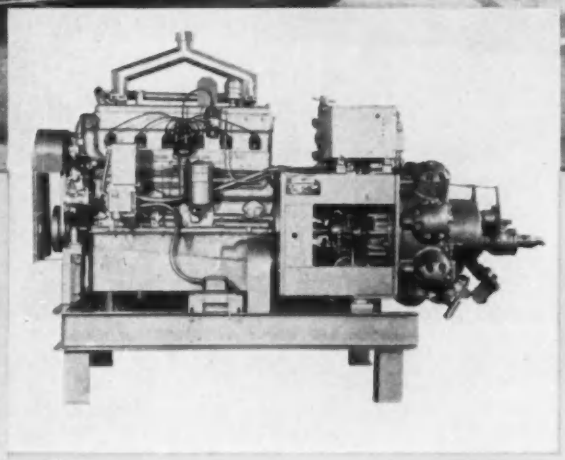
CHICAGO RAWHIDE MANUFACTURING COMPANY

1243 Elston Avenue • Chicago 22, Illinois

Offices in 55 principal cities

In Canada: Chicago Rawhide Mfg. Co. of Canada, Ltd., Brantford, Ontario

Export Sales: Geon International Corp., Great Neck, New York



A typical Ready-Power air conditioning unit is in the Hillcrest Country Club, Mt. Clemens, Michigan, where an International-powered system cools the club house and heats the swimming pool. The U-450 engine uses natural gas fuel to drive the compressor supplying liquid freon to a 70-ton Ready-Power Water Chiller Package. Ready-Power reports universal customer satisfaction with International-powered air conditioning equipment.

Power package for air conditioning

READY-POWER'S 25-year experience proves INTERNATIONAL superiority on thousands of engine applications

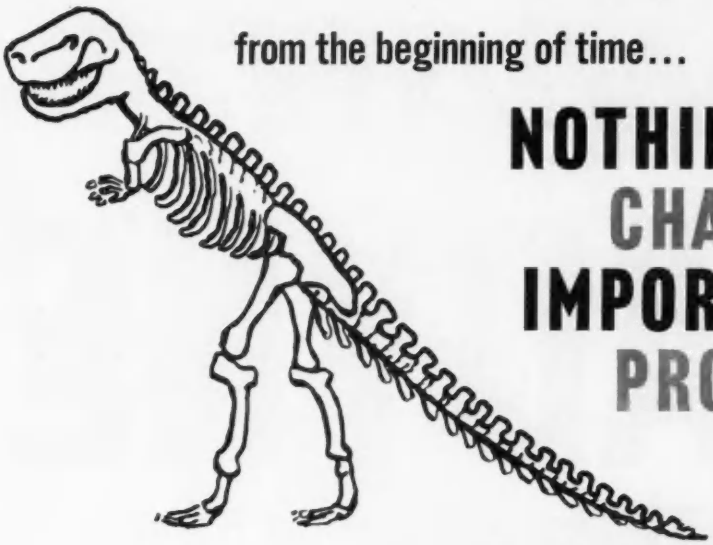
Here's another successful manufacturer reporting on the superiority of International engines. The Ready-Power Co., of Detroit has been designing and manufacturing engine-driven equipment for 36 years, has been an IH booster for 25 years. Ready-Power President H. D. Gumpper says, "Proven reliability of International engines plus excellent parts and service coverage, has led to the universal acceptance of Ready-Power engine generators and Ready-Power air conditioning equipment."

In 1935 Ready-Power introduced a line of International-powered electric plants, which now range in size from 5 to 200 KW. In 1945 came the Ready-Power line of International-powered air conditioning equipment. This experience of using thousands of IH engines proves that International power is best.

Your products, too, can benefit from the selling and engineering advantages of International design. Check the complete IH engine line—35 models from 16.8 to 385 max. hp—gasoline, LP gas, natural gas or diesel. Just call or write International Harvester Co., Engine Sales Dept., Construction Equipment Division, Melrose Park, Ill.

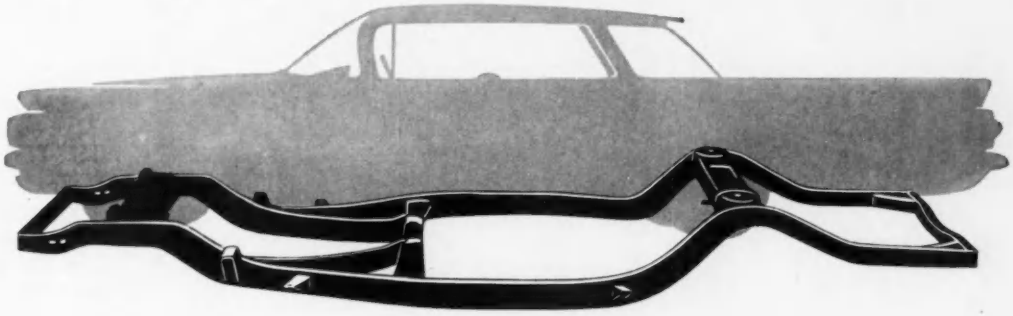
INTERNATIONAL® ENGINES

International Harvester Co.,
180 North Michigan Ave., Chicago 1, Illinois
A COMPLETE POWER PACKAGE



from the beginning of time...

NOTHING HAS CHANGED THE IMPORTANCE OF A PROPER FRAME!



As it was with the prehistoric dinosaur, the frame—or skeleton—is a vital part of modern passenger cars and trucks—is, in fact, the backbone of the vehicle. And, when all of the factors of rigidity, durability and load support are considered, the *separate* frame provides many important advantages over the unitized concept.

The separate frame benefits both car manufacturer *and* car owner. It's safe, absorbs road shocks with less noise transfer, offers more resistance to stresses and strains. The separate frame allows for flexibility as well as quick design changes—and it permits body repairs and replacements at lower cost.

The separate frame is not a static unchanging structure. Through the years its design has been constantly revised to meet new requirements for passenger comfort and safety. It will continue to be adapted to new driving and styling trends as they occur in the future.

For over 50 years Parish has been a leading producer of frames for passenger cars. We will be happy to place our extensive facilities and product know-how at your disposal in connection with any automotive frame or structural problems you may have.

P PARISH

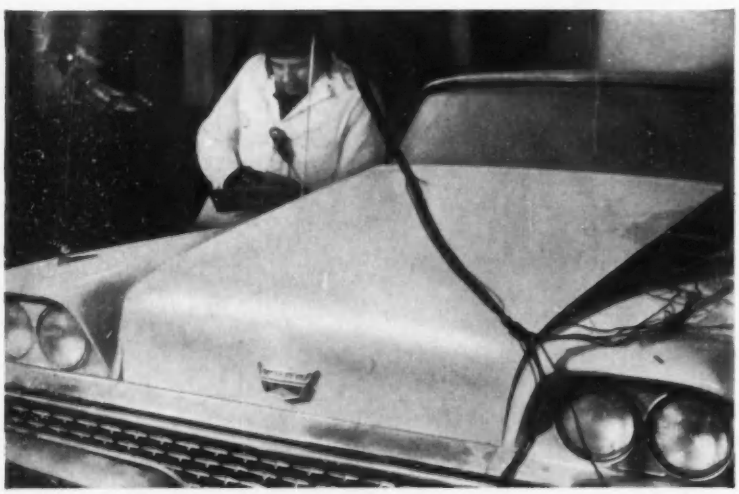
PARISH PRESSED STEEL

DANA Division of Dana Corporation / Reading, Penna.

● **DANA PRODUCTS:** Transmissions ● Universal Joints ● Propeller Shafts ● Axles ● Torque Converters ● Gear Boxes ● Power Take-Offs ● Power Take-off Joints ● Rail Car Drives ● Railway Generator Drives ● Stampings ● Spicer and Auburn Clutches ● Parish Frames ● Forgings.

NEW ANTI-

PARADYNE®



PARADYNE 41 PASSES STIFF ANTI-STALLING TESTS

The photograph shows a car undergoing stalling tests in a controlled temperature room. Paradyne 41 inhibited gasoline gave outstanding performance under the most critical conditions.

provides maximum protection against engine stalling

Paradyne 41 prevents troublesome carburetor icing . . . the most common cause of stalling in the fall, winter and spring seasons. A combination of phosphorus-containing compounds, Paradyne 41 forms a protective water- and ice-repellent film on metal surfaces . . . preventing agglomeration of ice crystals on carburetor surfaces.

ALSO PREVENTS RUST

Test panels immersed in Paradyne 41 inhibited gasoline showed no rust after 40 days.

SAVES MONEY ON PHOSPHORUS

At concentrations normally used for anti-icing, Paradyne 41 provides an appreciable portion of the phosphorus required to modify combustion deposits...thus reducing the amount of additional phosphorus additive required to prevent misfiring and surface ignition.

PERFORMANCE PROVEN BY THOROUGH FIELD TESTING

Extensive field tests, closely controlled test car studies and large-scale distribution studies . . . substantiate service qualities shown by Paradyne 41 in laboratory test engines.

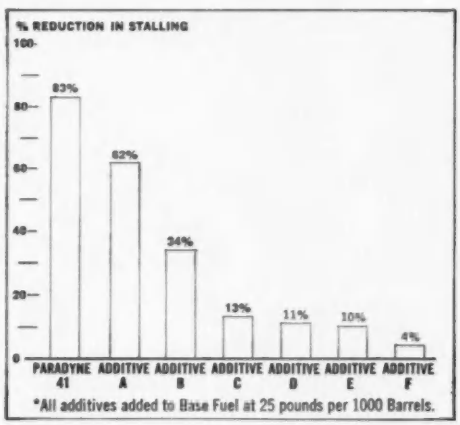
EASY STORAGE AND HANDLING

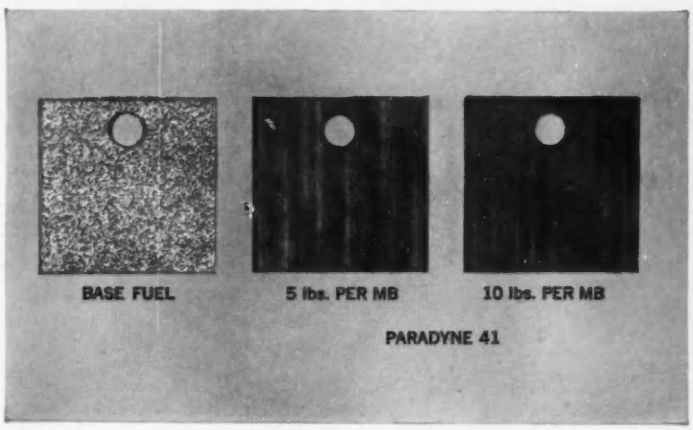
May be handled as a petroleum product . . . with normal precautions used in handling phosphorus additives.

ENJAY

ADDITIVES

STALL 41 GASOLINE ADDITIVE!





PARADYNE 41 PROVEN SUPERIOR

The bar chart shows the anti-stalling effect of Paradyne 41 and six other leading additives when compared with the additive-free gasoline. Under test conditions, additive-free gasoline allowed 22 out of 25 possible stalls. Paradyne 41 reduced the stalls to less than four out of 25 – a reduction of over 83%. Paradyne 41 excels in anti-icing effectiveness even under the most critical temperature and humidity weather conditions.

CALL UPON ENJAY FOR PRESCRIPTION-BALANCED ADDITIVES THAT

...meet your exacting specifications
...help you market your products successfully

The new Paradyne 41 Technical Service Bulletin, and information about improving your product's performance with a Prescription-Balanced Paramins Package, are yours for the asking.

TEST PANELS SHOW PARADYNE 41 ANTI-RUST EFFECTIVENESS

Rusted panel at left was immersed in gasoline over synthetic sea water for three days. The other panels were subjected to same conditions for 40 days, but gasoline was inhibited by small concentrations of Paradyne 41. Note that these panels are rust free.

ENJAY SERVES YOU

...with a *complete* line of petrochemicals to improve fuels and lubes • with a larger staff devoted exclusively to additives research and manufacture ... a staff available to help you meet your special additives requirements • with quality controls at every production step to assure that each order meets specifications • with expedited deliveries from Enjay product centers across the country.

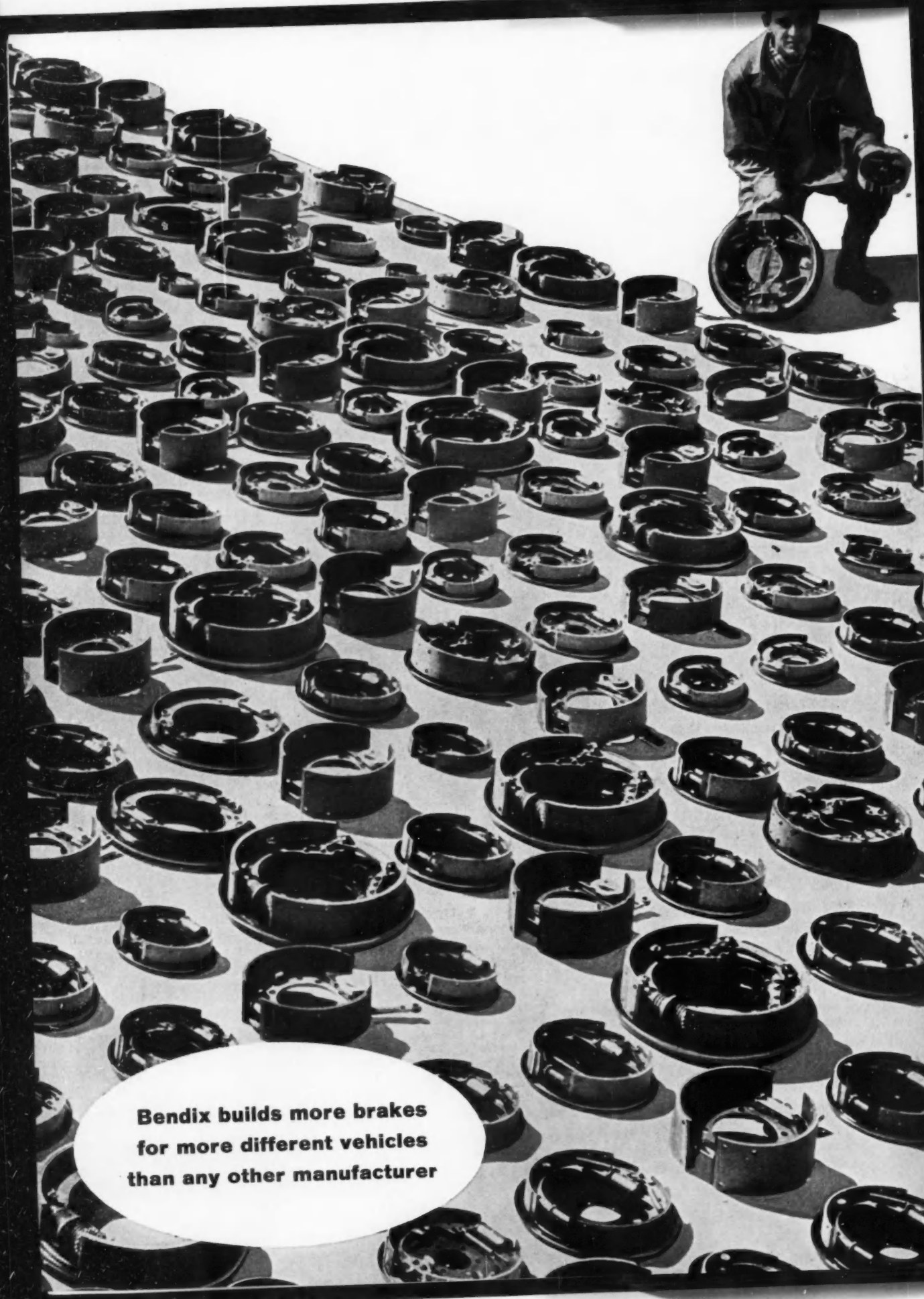
Want more information? Contact the nearest Enjay office: (Home Office) 15 West 51st Street, New York 19, N.Y. (Other Offices) Akron • Boston • Charlotte • Chicago • Detroit • Houston • Los Angeles • New Orleans • Tulsa • Toronto

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY
ADDITIVES


Bendix builds more brakes
for more different vehicles
than any other manufacturer

400 REASONS WHY:

It pays to put your braking problems up to Bendix

Shown at the left are just a few of the automotive brakes now in production at Bendix. Actually, our current production schedules call for *more than 400 different types of automotive brakes, alone.* § There are many reasons for this industry-wide faith in Bendix ability. Most of these reasons, however, can be listed under the headings of experience and know-how. § In 40 years of intimate association with the problems of automotive braking, Bendix has made major contributions. These include four-wheel brakes, Duo-Servo® braking, automatic brake adjusters, and power braking —among others. § Because engineering and manufacturing dependable braking systems is our business, we are more than ordinarily interested in testing. *Bendix conducts more brake pre-testing than any other organization in the world.* Exhaustive laboratory- and road-testing are conducted on each and every brake design before it is approved for production. You can feel confident in bringing your braking problems to Bendix. With proved capabilities and careful attention to every detail, Bendix has the answers you seek. Call on our Customer Application Engineers at any time for information and advice. There is no obligation.

BRAKE HEADQUARTERS OF THE WORLD

Bendix PRODUCTS DIVISION South Bend, IND.

THE Bendix CORPORATION

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Annealing: Its Uses with Alloy Steels

Broadly speaking, the primary purpose of annealing is to soften steel and make it more workable. Annealing, as applied to alloy steels, may be defined as a process that heats above, and furnace-cools through, the critical range at a controlled, specified rate of speed; or that heats to a point within, and furnace-cools to a point below, the critical range. In either case, the choice depends upon the structure and maximum hardness desired.

The first method produces a lamellar pearlitic structure, while the second creates a spheroidized condition. These will be discussed separately in the following paragraphs:

(1) *Lamellar pearlitic structure.* It should be mentioned at once that this structure can be obtained both as described above and by a modified method known as isothermal annealing. In the isothermal process, the steel is heated above the critical temperature (austenitized), then transformed at a predetermined temperature, which depends upon the analysis. This operation requires two furnaces or salt baths —one for austenitizing, one for transformation.

Lamellar pearlitic structures are generally associated with machinability in carbon ranges from 0.20 to 0.60 pct, provided the hardness does not exceed the optimum maximum Brinell numeral. This is especially true where critical tooling is involved. It is a very versatile structure, as it gives best results in such operations as broaching, tapping, threading, deep drilling, boring, milling, and tooling as applied on single- and multiple-spindle bar automatic machines.

(2) *Spheroidized structure.* There are two general fields of use for this type of structure when alloy steels are employed. In the low and medium carbon ranges, spheroidization is necessary for cold-shaping operations, such as heading, extruding, drawing. In the higher carbon ranges (over 0.60 pct), it is mandatory where machining is involved, because it tends to lower the hardness of the steel.

If you want more details about these and other uses of annealing, and the results to be expected, by all means consult with our technical staff. And when you need alloy steels, Bethlehem can offer the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

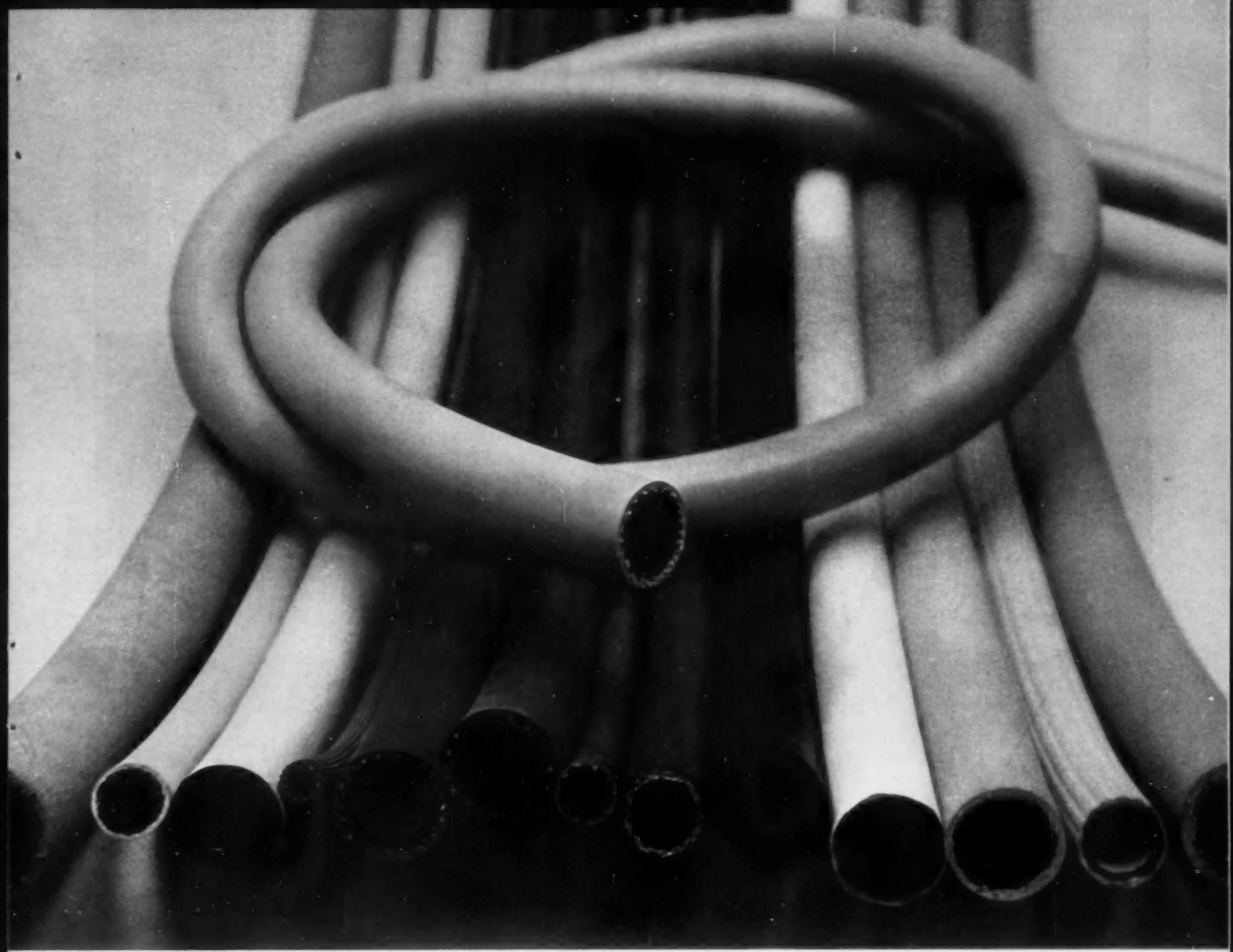
BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Naugatuck PARACRIL OZO

THE OIL-RESISTANT, OZONE-RESISTANT NITRILE RUBBER



Great new advance in hose rubber

New PARACRIL OZO—exciting development from the laboratories of Naugatuck Chemical—offers the makers and users of rubber hose a combination of properties never before available.

Hose of every description, for practically every purpose, can be tougher, less bothered by abrasion, more oil and weather resistant than ever before. *And it can be produced in any permanent color desired!*

New PARACRIL OZO offers such advantages as:

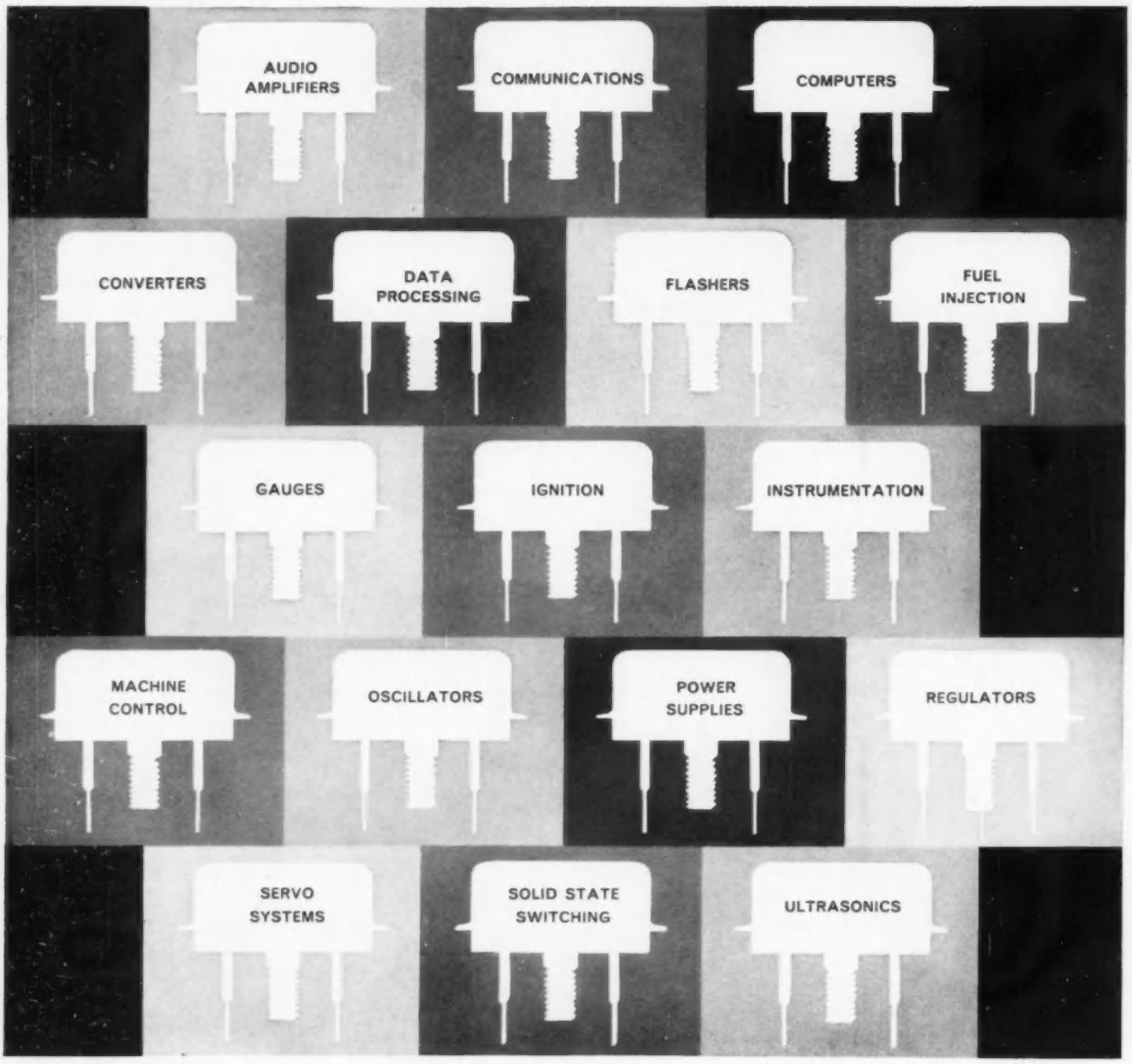
- significantly superior ozone resistance
- excellent fuel and oil resistance
- several times greater abrasion resistance
- permanent retention of bright, uniform colors

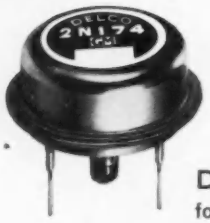
Discover first hand the dramatic new sales possibilities this proven new rubber offers you. In increased product quality. In new production economy. For full information and whatever technical assistance you may require, contact your Naugatuck representative or write the address below today.

Naugatuck Chemical

Division of United States Rubber Company Dept. A Elm Street Naugatuck, Connecticut

Rubber Chemicals · Synthetic Rubber · Plastics · Agricultural Chemicals · Reclaimed Rubber · Latices · CANADA: Naugatuck Chemicals Division, Dominion Rubber Co., Ltd., Elmira, Ontario CABLE: Rubexport, N. Y.





ONE TRANSISTOR— HUNDREDS OF USES

DELCO RADIO'S VERSATILE 2N174

For top performance in a wide, wide range of applications, depend on Delco Radio's 2N174.

■ This multi-purpose PNP germanium transistor is designed for general use with 28-volt power supplies, and for use with 12-volt power supplies where high reliability is desired despite the presence of voltage transients. ■ It has a high maximum emitter current of 15 amperes, a maximum collector diode rating of 80 volts and a thermal resistance below .8°C per watt. The maximum power dissipation at 71°C mounting base temperature is 30 watts. Low saturation resistance gives high efficiency in switching operations. ■ The 2N174 is versatile, rugged, reliable, stable and low priced. For more details or applications assistance on the 2N174 or other highly reliable Delco transistors, contact your nearest Delco Radio sales office.

DELCO RADIO
DEPENDABILITY
RELIABILITY

Newark, New Jersey
1180 Raymond Boulevard
Tel.: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel.: Exbrook 3-1465

Chicago, Illinois
5750 West 51st Street
Tel.: Portsmouth 7-3500

Detroit, Michigan
57 Harper Avenue
Tel.: Trinity 3-6560

Division of General Motors · Kokomo, Indiana

Want to Convert Rotary Motion into Linear?

The EATON OVERRUNNING BALL-SCREW *may be your answer*

The Eaton Overrunning Ball-Screw is a simple, versatile mechanism that converts rotary motion into linear. In such basic applications as actuators for opening doors and windows, and positioners of various kinds this device offers the designer many advantages:

- **Nut stops at end of travel, and overruns without jamming**
- **No limit switches or anti-stall devices are required**
- **High mechanical efficiencies reduce power requirement**
- **Can be installed in inaccessible or sealed-in locations for remote control operation**
- **Permits compact, space-saving assemblies**

The Eaton Overrunning Ball-Screw may be adapted to an almost endless number of applications. Send for illustrated descriptive literature.

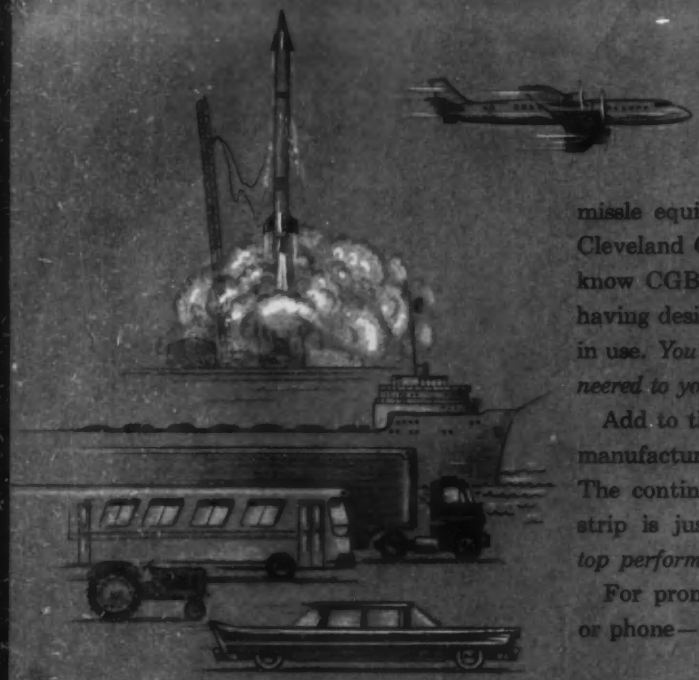
SOME POSSIBLE APPLICATIONS

Window Lifts
Seat Actuators
Trunk lid lifts
Die table positioners
Door controls
Convertible top lifts
Chair Adjusters
Speed control devices
Mechanical toys
Business machines
Surgical and hospital equipment

EATON

EATON

SAGINAW DIVISION
MANUFACTURING COMPANY
9771 FRENCH ROAD • DETROIT 13, MICHIGAN



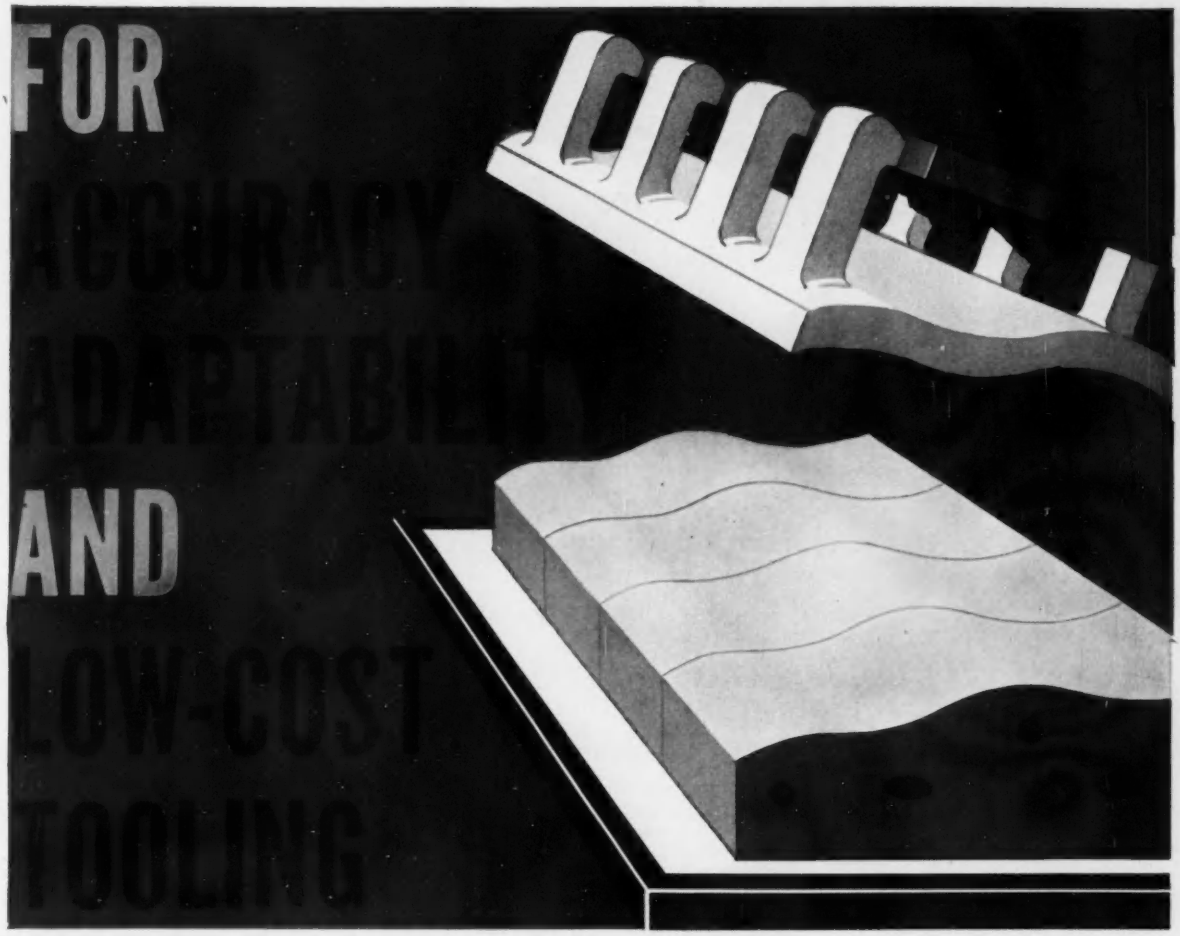
Engineers who specify original equipment bearings for most American cars, trucks, tractors, construction equipment, aviation-missile equipment, and Diesel and marine engines prefer Cleveland Graphite Bronze for reasons like this . . . They know CGB has pioneered in bearing and bushing design, having designed and introduced the majority of types now in use. *You are assured of a bearing, bushing or washer engineered to your specific application.*

Add to this the skill of CGB as a high quality precision manufacturer—with many exclusive production techniques. The continuous casting of babbit or copper-lead to steel strip is just one example. *Engineers are thus assured of top performance—long, trouble-free life.*

For prompt attention to your application—write, wire or phone—a qualified engineer will work with you.

More engineers prefer this bearing and bushing line than any other!

CLEVELAND GRAPHITE BRONZE
17000 ST. CLAIR AVENUE • CLEVELAND 10, OHIO
DIVISION OF CLEVITE CORPORATION
CHICAGO DETROIT LOS ANGELES NEW YORK



BESTWALL DENSITE K-33

Field Experience
+
Customer Needs
+
Modern Research
+
Modern Plants
=
Full Line of
Bestwall Industrial Products.

May we have the opportunity to prove to you that . . .

A premium product at regular Densite price. Densite K-33 is an ideal gypsum cement for die sinking, for epoxy resin molds, for vacuum forming molds, for splash casting and built-up template work. It offers these advantages:

Lowest expansion of tooling Densites—Insures dimensionally accurate tools and check fixtures

Adequate plasticity—Allows ample time for conventional splash casting techniques

Colored for easy identification—Also minimizes eyestrain during checking operations (available white, if specified)

Hardest surface—Monotron hardness 90-100 at use consistency, with measured surface finishes 16-60 micro-inches

Densite K-33 and all other Densites are non-toxic.

YOUR BEST BUY IS FIREPROOF GYPSUM BESTWALL BUILDING PRODUCTS

BESTWALL GYPSUM COMPANY
Ardmore, Pennsylvania
Plants and offices throughout the United States

DIVISION OF CLEVITE CORPORATION
CHICAGO DETROIT LOS ANGELES NEW YORK

General Motors Reliability in Action...

Cool Air in Arizona!

Compact, efficient, performance-proved—Harrison Cool-Pack "under-the-dash" Air Conditioner is another reliable GM product.

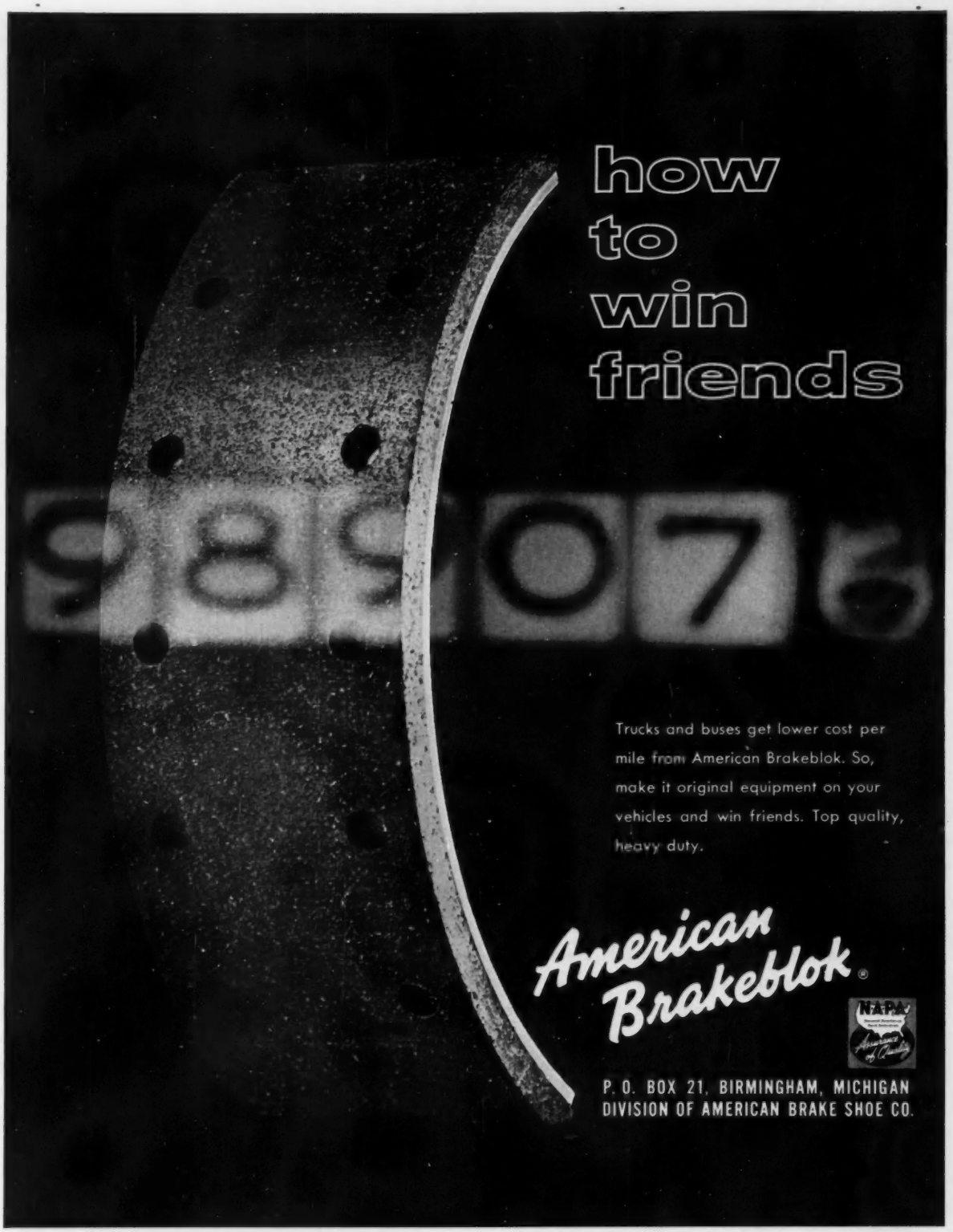
HARRISON AIR CONDITIONERS ARE PERFORMANCE PROVED IN TORTUROUS TEMPERATURE TESTS AT GENERAL MOTORS DESERT PROVING GROUND!

Blazing heat and desert dust make the Sonora country in Arizona ideal for testing car air conditioning. Here is where Harrison Air Conditioned cars are put through their paces . . . hour-after-hour on the high-speed track—mile-after-mile over rugged roads. Grueling performance tests like this are standard procedure at Harrison—and it pays off for today's drivers in maximum product efficiency and reliability on the road. The Arizona Proving Ground is typical of GM-Harrison engineering and testing facilities—the most modern and complete in the automotive heat transfer industry. Reliability through research is one reason why Harrison has been the leader in product performance, value and dependability for a half century. If you have temperature problems . . . passenger comfort or vehicle efficiency . . . look to the leader. Look to Harrison for the answers!

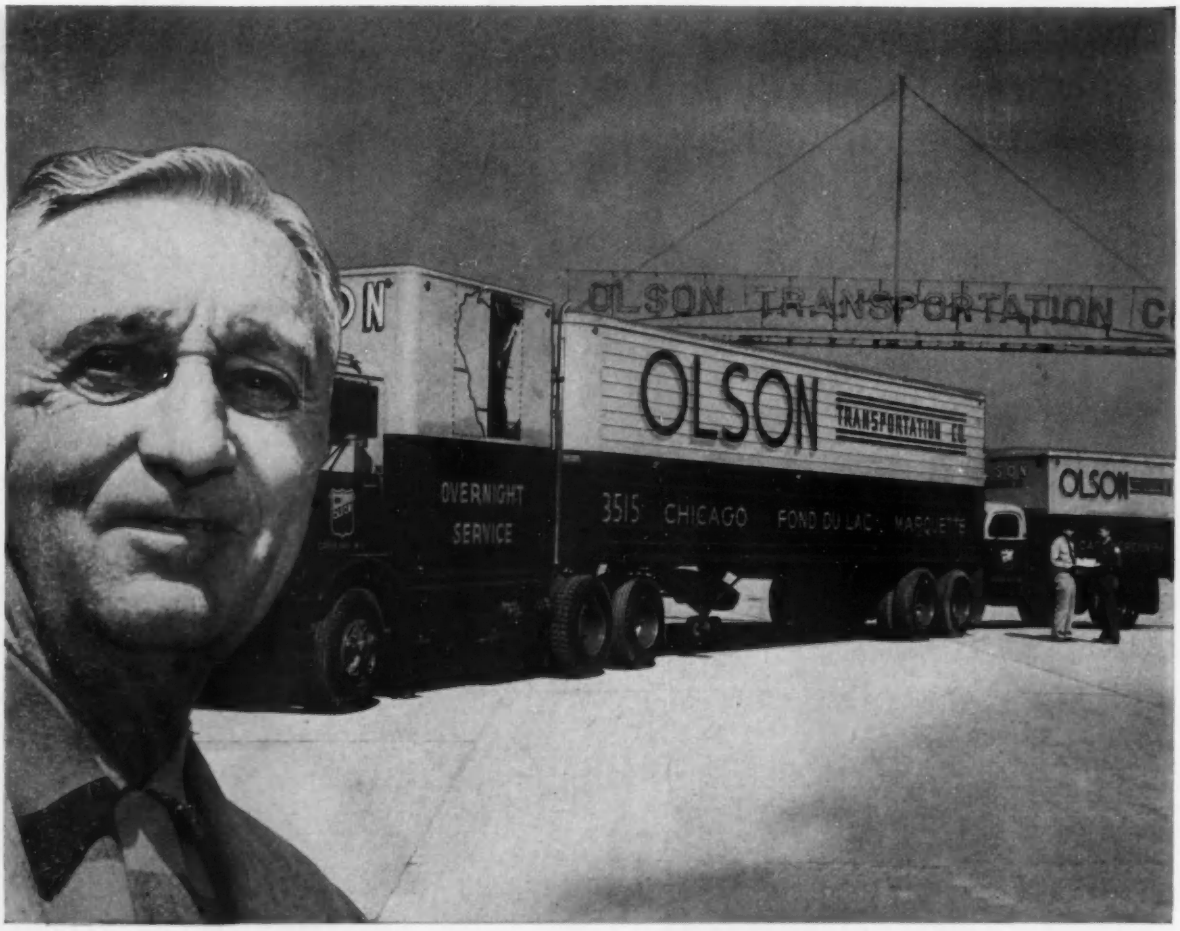
GM TEMPERATURES MADE TO ORDER
HARRISON

AUTOMOTIVE RADIATORS • OIL COOLERS • THERMOSTATS • AIR CONDITIONERS • HEATERS • DEFROSTERS

HARRISON RADIATOR DIVISION, GENERAL MOTORS CORPORATION, LOCKPORT, NEW YORK


how
to
win
friends
Trucks and buses get lower cost per mile from American Brakeblok. So, make it original equipment on your vehicles and win friends. Top quality, heavy duty.
American Brakeblok®
NAPA
P. O. BOX 21, BIRMINGHAM, MICHIGAN
DIVISION OF AMERICAN BRAKE SHOE CO.

AMERICAN BRAKEBLOK



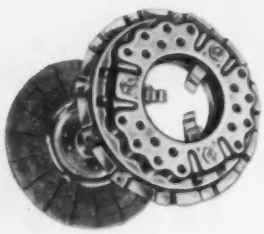
"We average more miles with LIPE CLUTCHES"

says Olson Transportation Co., Green Bay, Wisconsin

M. J. Madigan, Olson Maintenance Superintendent, remarks: "Some time back, we decided to give Lipe Clutches a thorough tryout as interchanges for original equipment. Our records show that they have produced more miles before overhaul than the clutches supplied with our units when new. Needless to say, we are very satisfied with these results."

Measure Lipe Clutch value by any standard you like . . . by ton-miles per year, by number of engagements or miles between teardowns, by vehicle use per repair dollar . . . and you'll agree with reports from all over the country that Lipe delivers more profit-building performance per dollar of cost. That's why . . .

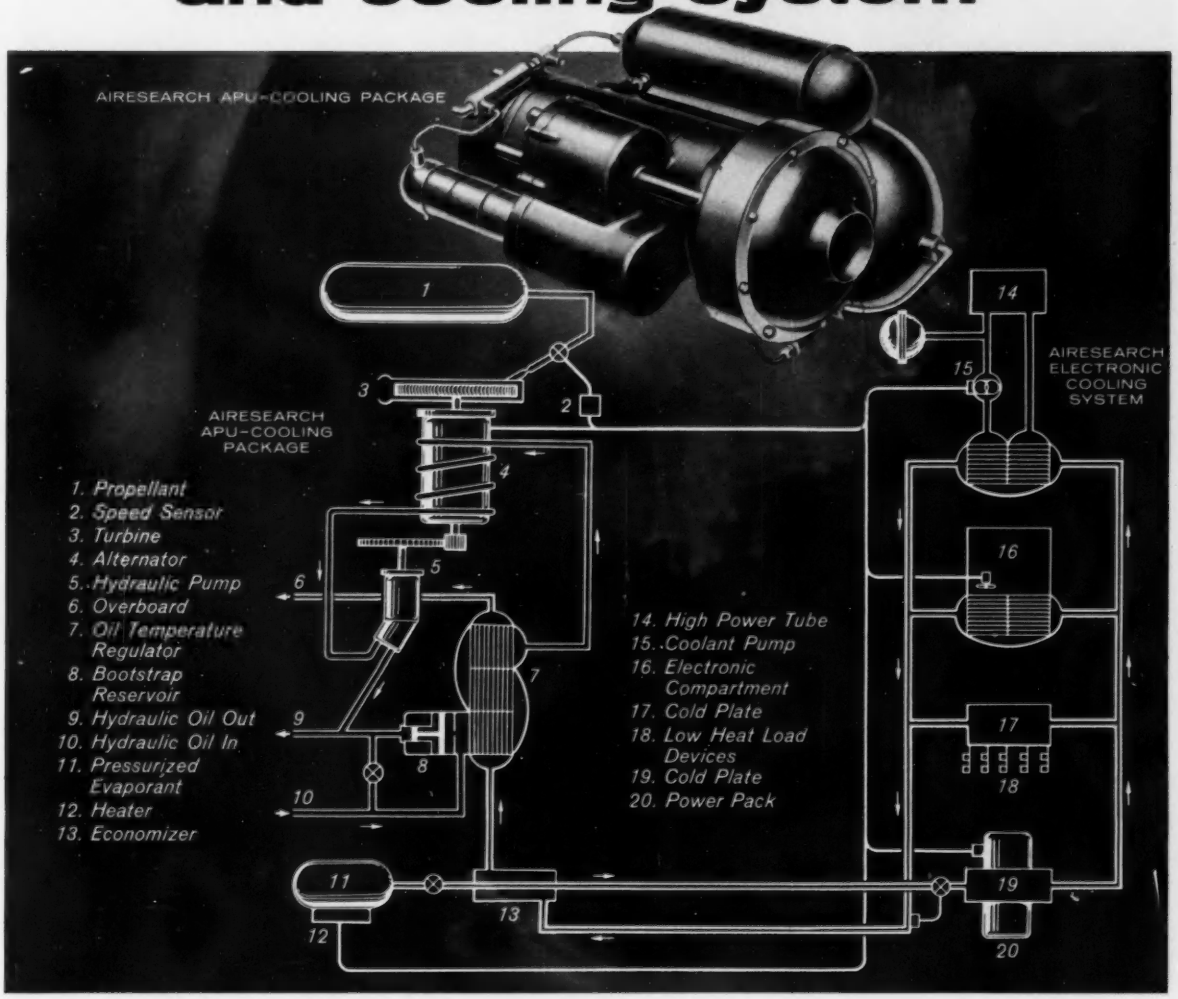
***the trend is to* LIPE!**



There is a Lipe Clutch to meet requirements of vehicles 18,000 lbs. G.V.W. and up; for torque capacities from 200 to 3000 ft. lbs. For application assistance and specific data, contact the Company direct.

LIPE-ROLLWAY CORPORATION
SYRACUSE 1, N. Y.

Integrated accessory power and cooling system



meets the most advanced missile and space vehicle requirements

AiResearch has developed a *single* system package for missiles and space vehicles to meet increasing accessory power and cooling load requirements in the face of decreasing size and weight allowances.

This integrated accessory power and cooling system supplies hydraulic power for actuating systems, 3200 or 400 cycle three-phase electric power for guidance and control, and at the same time provides cooling both for the APU and all electronic equipment operating in the missile or space vehicle.

The cooling system in the example shown here uses liquid ammonia as the expendable evaporant, and each heat load area has a separate temperature control valve. Alternator and controls, turbine assembly and APU liquid propellant fuel tank are patterned after operationally proven components.

World leader in the design and manufacture of cooling and accessory power systems, AiResearch has delivered more missile APUs than any other company, and is the leader in advanced electronic cooling systems for aircraft, missiles and spacecraft.

AiResearch design and manufacturing experience in these two fields includes: liquid and solid propellant APUs; hydraulic and hot gas actuators and control systems; 3200 and 400 cycle alternators; cold plates; expendable and closed cycle gas and liquid cooling systems; cryogenic cooling systems.

Please direct inquiries to Los Angeles.

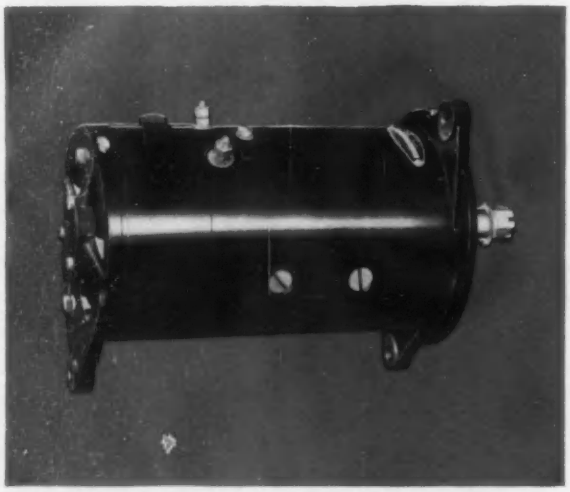
THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

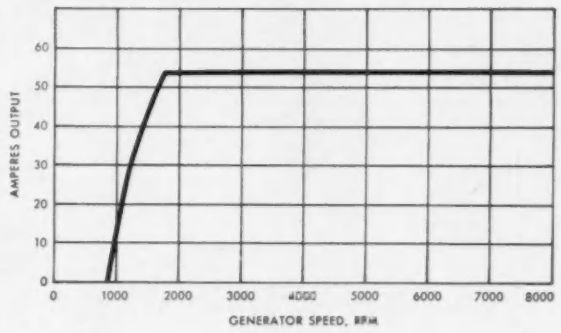
Los Angeles 45, California • Phoenix, Arizona

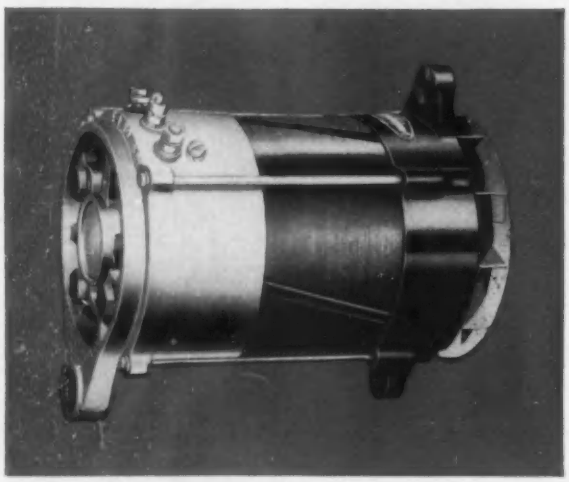
Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

TAILOR YOUR TRUCKS

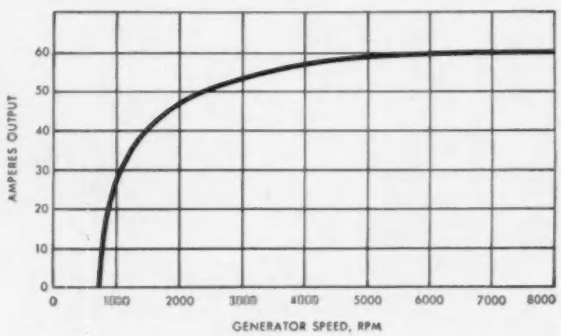


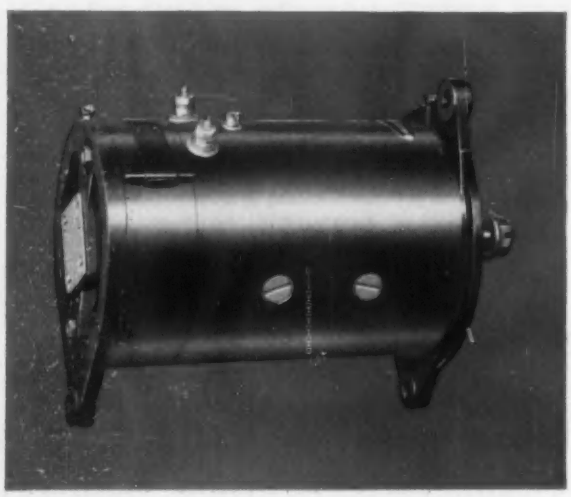
1106991 EXTRA-OUTPUT D.C. GENERATOR—12 volts • 55 amperes • 12 amperes at idle—For cross-country trucks, school buses and other vehicles with extra electrical equipment.



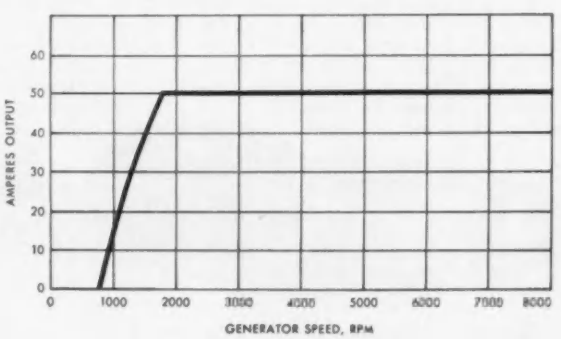


1117070 SELF-RECTIFYING A.C. GENERATOR—12 volts • 60 amperes • 27 amperes at idle—For high-duty vehicles with heavy electrical loads . . . operating at all speed ranges. Ideal for excessive low-speed operation and curb-idling.

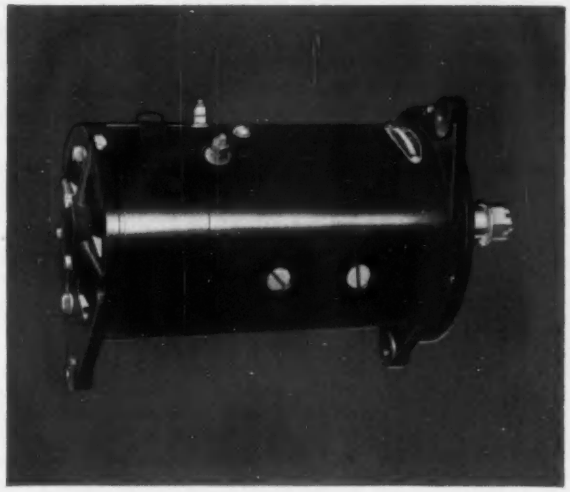




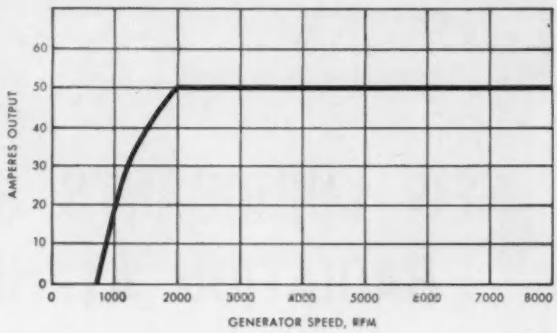
1106985 EXTRA-OUTPUT D.C. GENERATOR—12 volts • 50 amperes • 14 amperes at idle—Short frame generator for difficult mounting applications. For vehicles in city and suburban use. Not for cross-country operation.

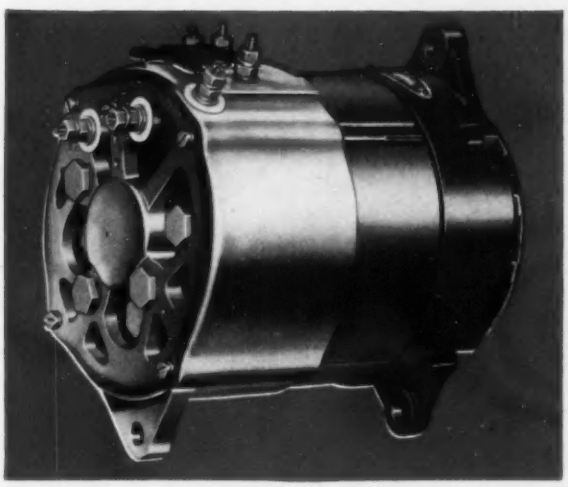


TO JOB CONDITIONS

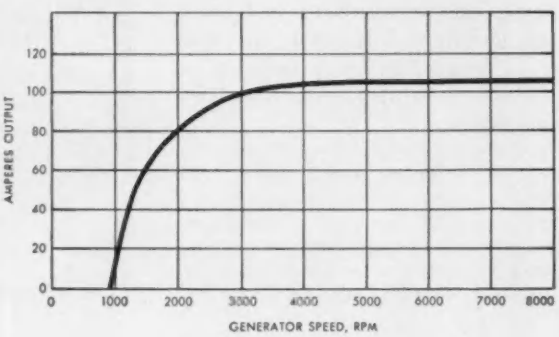


1106986 EXTRA-OUTPUT D.C. GENERATOR—12 volts • 50 amperes • 20 amperes at idle—For metropolitan trucks and school buses, with extra electrical equipment . . . operating at low speeds and with engine idling most of the time.





1117115 SELF-RECTIFYING A.C. GENERATOR—12 volts • 105 amperes • 10 amperes at idle—For high-duty vehicles with extra-heavy electrical loads . . . operating at all speeds. A.C. voltage available for 110 V conversion.



Delco-Remy offers a complete line of D.C. and A.C.•D.C. generators that are right for the job.

Demands on the electrical systems of trucks vary with their use. For best performance, whether the vehicles be new or already in service, the electrical equipment should be job-matched to meet those demands.

Do your trucks have extra electrical equipment? Operate cross-country, around town or off the road? Do they travel at sustained highway speeds, or with plenty of stop and go? Whatever their assignment, there are Delco-Remy extra-output generators and regulators job-matched to meet the electric power needs *exactly*.

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At Dow, where the test tube often serves as test track for automotive fluids, there is a dedicated group of men who are exceedingly car conscious. These men of Dow's Automotive Chemicals Laboratories—car buffs in their own right—work together enthusiastically with automotive engineers on a wide range of developmental applications, both current and future. The results of this natural cooperation may take the form of a better brake fluid, a safer metal cleaner, or a synthetic lubricant . . . one with properties for "years ahead" applications such as the new polyphenyl ethers . . .

NEW LUBRICANTS SHRUG OFF OXIDATION, RADIATION AT HIGH TEMPERATURES

Polyphenyl ethers exhibit marked improvements in lubricating properties and the ability to "take it" under adverse conditions. They're the result of a long range research program on synthetic lubricants at Dow . . . one of primary interest to forward-thinking automotive engineers.

Continuous research on synthetic lubricants in Dow's Automotive Chemicals Laboratories has spotlighted the polyphenyl ethers. These chemical materials have exceptional lubricating properties and excellent stability in the presence of oxidation, radiation and high heat.

Their lubricity is comparable to the diester lubricants; in the Shell 4-Ball Wear Test, for example, the scar diameter is 0.9 mm. when operating at 600 rpm and 400°F for one hour at a loading of 50 kg. Polyphenyl ethers are resistant to radiation—changes in viscosity are minor after absorption of 1×10^{11} ergs per gram. In a non-oxidizing atmosphere, some polyphenyl ethers withstand 800°F for about 100 hours. In an oxidizing environment polyphenyl ethers can be used for long periods of time at temperatures up to 600°F. Low temperature use is currently limited to 30°F.

Dow is currently working with industry to perfect practical applications. The high resistance to radiation of polyphenyl ethers suggests their use in nuclear-powered aircraft and surface vehicles.

This research and developmental work is part of an over-all program on synthetic lubricants of all types, including the large and versatile polyglycol family. The polyglycols are characterized by many desirable lubricating properties. They have a high natural viscosity index, are non-carbonizing, and display improved oxidation and shear stability, sludge and varnish resistance. Polyglycol lubricants are used today in such diverse applications as crankcases, gas turbine engines, and hydraulic fluids.

Synthetic lubricants pass lubricity exam for power steering pumps.

V. I. improver research shifts into high

Although viscosity index improvers are young as additives go, they're doing a man-sized job in many lubricating oils. Continuous research on them

is being carried out at Dow—in fact, it's currently being speeded up in Dow's Automotive Chemicals Laboratories. Why? Because the tasks V.I. improvers are asked to perform have rapidly multiplied. Present "extra-curricular" jobs as pour point depressants and detergents are varied and complex; yet vastly improved properties will be expected of the V.I. improvers of a few years from now.

As an example of the specialized, modern research equipment utilized in this work: Dow has developed an apparatus that simulates 20,000 miles of road testing in just one hour's time! Similar testing devices are now being perfected in the lab.

Shear-testing V.I. improvers under "road test" conditions.

That settles it!

When plant engineers have an industrial waste problem, they often find the answer in Dow's family of flocculating agents. Separan® NP10, for example, speeds settling rates of solids in solution and improves clarity. It also does an outstanding job in water treatment and in most types of processing operations.

Waste solids in solution settle out quickly with Separan NP10.

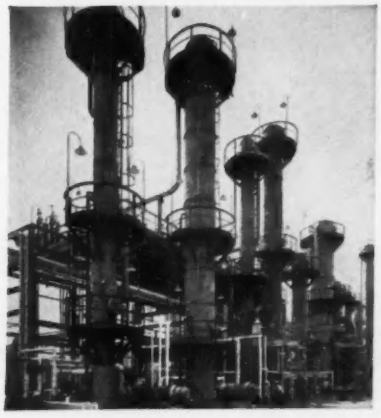
Polyols for every purpose

Dow offers industry "the world's widest line of polyols." These specialized chemicals are used in a broad range of fluids of interest to automotive engineers: brake and power steering fluids, synthetic lubricants and transmission fluids, coolants, antifreezes and hydraulic fluids.

Some of the newest of the automotive materials made from Dow polyols are the urethane foams used as seat cushioning material. Dow provides foam manufacturers with Voranol*—special resin-grade polyglycols tailored to meet the exacting requirements of the flexible foam industry. Because Dow is *basic* in polyols, it can provide custom-made materials best suited for any particular customer application. There's practically no limit to the kinds of polyols Dow can produce!

*TRADEMARK

From Dow operations like this come the "world's widest line of polyols."



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The men of the Dow Automotive Chemicals Laboratories are leading with their chins. They welcome any technical chemical or chemical engineering problem—on current or future applications—concerning automotive chemicals. Your inquiry will receive prompt attention by our research staff. Contact the Dow sales office near you or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Chemicals Merchandising Dept. 403EN7.

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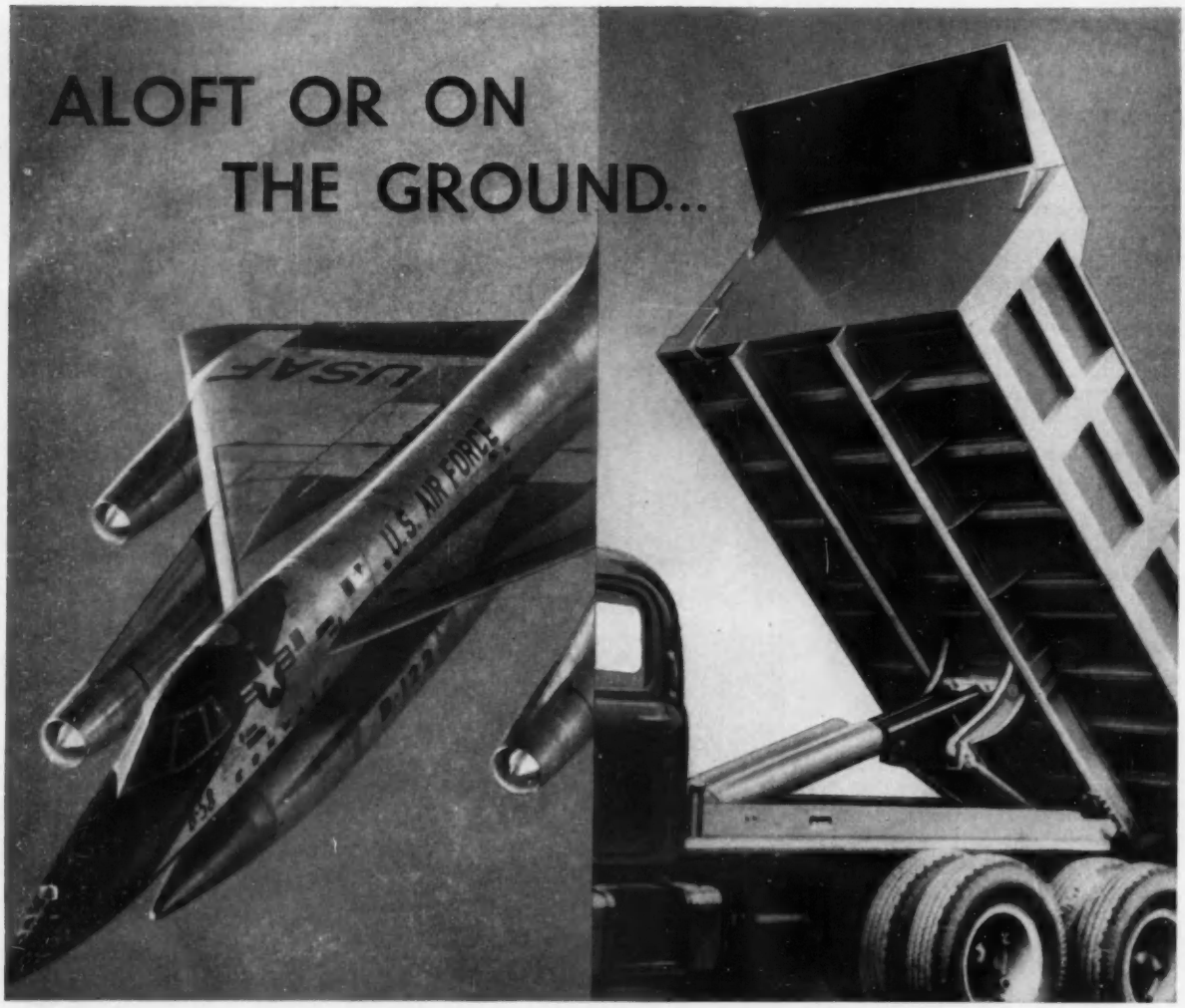

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"With Reichhold POLYLITE Polyester resin we have achieved the most efficient, least costly method of production for our compression molded automotive fresh air ducts." This report comes from Lester F. Barnum, Vice President and Treasurer of Barnum Brothers Fibre Company, East Detroit, Mich.

"POLYLITE gives us about four times the curing speed obtained with other types of molding material. Press time with POLYLITE is only 38 to 42 seconds as compared to three minutes with other materials," continues Mr. Barnum.

As to final product, he says, "the resin exhibits exceptional impact and flexural strength as well as resistance to crazing and warping. It enables us to turn out a product that exceeds our customers' rigid specifications."

Perhaps there is a Reichhold POLYLITE Polyester resin that can help increase the efficiency of your production. Why not contact RCI and check the complete line of POLYLITE resins — not only for compression molding, but also for laminating, casting, structural layup, impregnating, encapsulating, rigid polyurethane foam production, surface coating, corrugated and flat sheet production and matched die molding.

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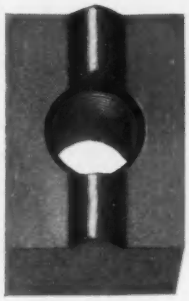
ACCURACY, DURABILITY and ECONOMY are important characteristics of these sintered metal automotive suspension parts by Delco Moraine. Vital components such as these are typical results of close collaboration between Delco Moraine and its customers—an effective liaison that functions from idea through design and development to production. They also confirm Delco Moraine's equally important capabilities for making deliveries in quantity and on time!



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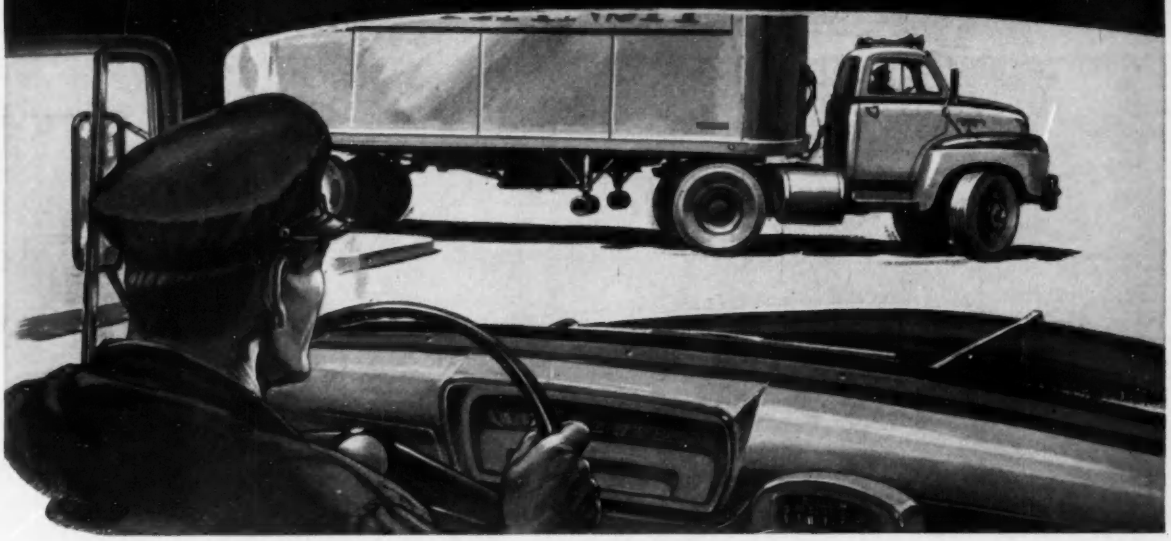

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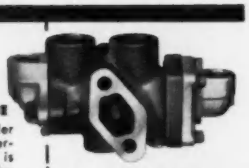
TRACTOR-TRAILER PROTECTION VALVES

WAGNER EMERGENCY BRAKE VALVE
provides "push-pull" manual control to activate the tractor's emergency protection system and to trigger emergency braking on the trailer.

WAGNER TRAILER RELAY EMERGENCY VALVE
fully applies the trailer brakes when the emergency brake valve is actuated manually by the driver, or automatically if the tractor system pressure drops to an unsafe value.



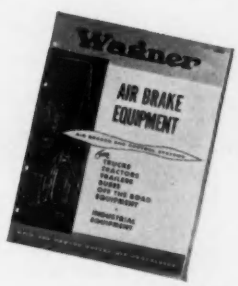
WAGNER TRACTOR AIR LINE PROTECTION VALVE
automatically isolates the tractor air supply by sealing the service and emergency air lines if the trailer is uncoupled, breaks away or loses its air supply. It also automatically activates trailer emergency valve to apply trailer brakes if tractor system pressure drops to an unsafe value.

Braking emergencies are something truckers have to live with. But, they can live with them a lot more safely if you equip the vehicles you make with Wagner Lockheed Emergency Brake Valves and Tractor Air Line Protection Valves. These valves, when used with the Wagner Trailer Relay Emergency Valve, give drivers of your vehicles safe emergency braking.

Wagner builds components for *all* braking systems —air or hydraulic; everything from the actuating system to the foundation brakes. REMEMBER, when you equip the vehicles you manufacture with Wagner Lockheed Emergency Brake Valves and Tractor Air Line Protection Valves, you add safety and low-maintenance features that build customer acceptance.

CONSULT YOUR WAGNER AIR BRAKE SPECIALIST

Let him help you with your specifications, and also ask him about the engineering consulting service available from Wagner.



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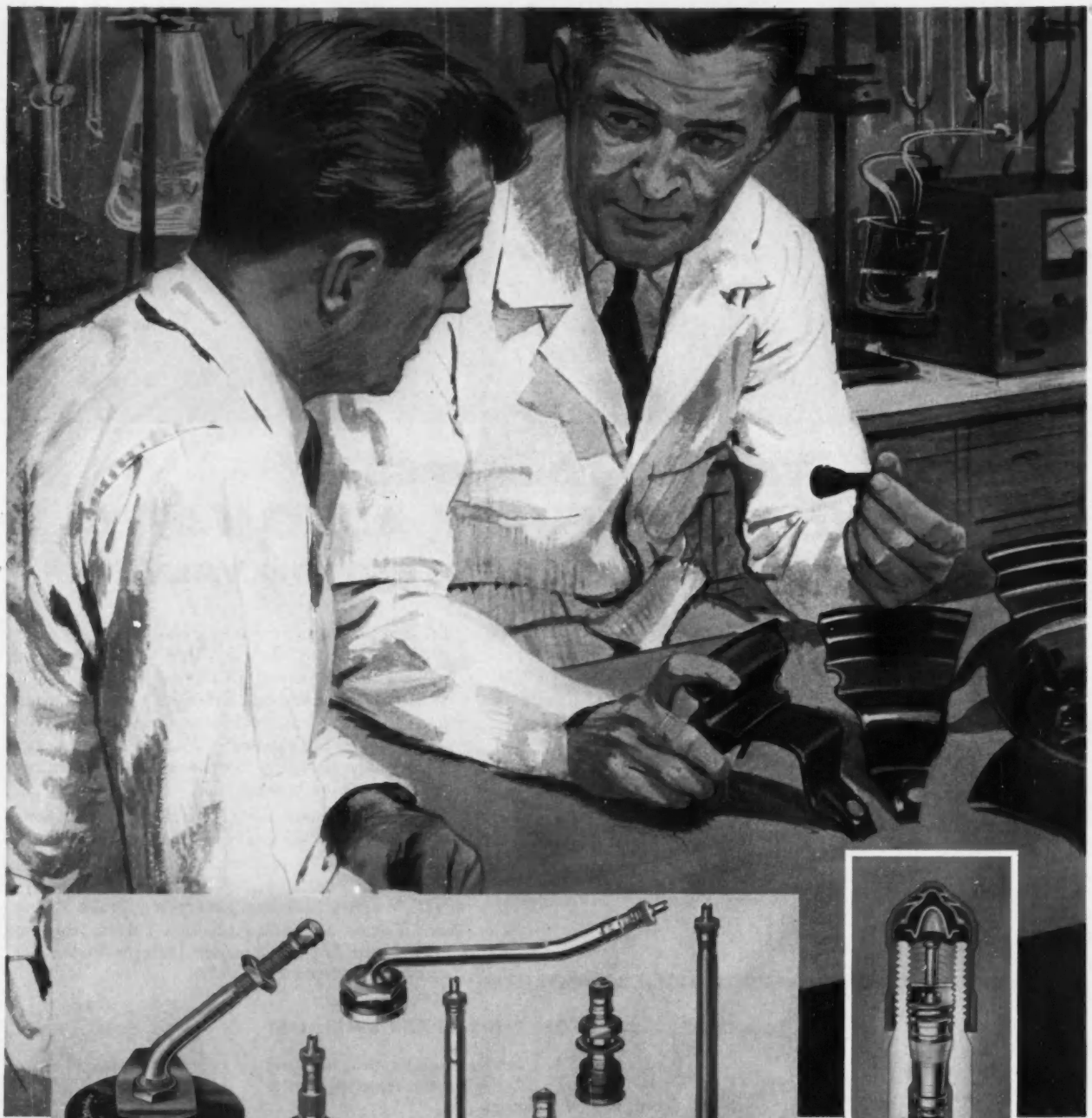
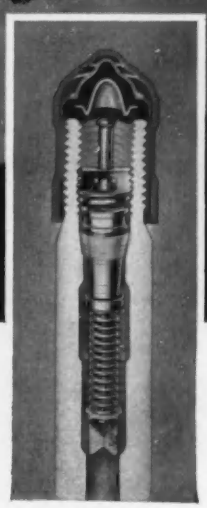
Continuing Research works to





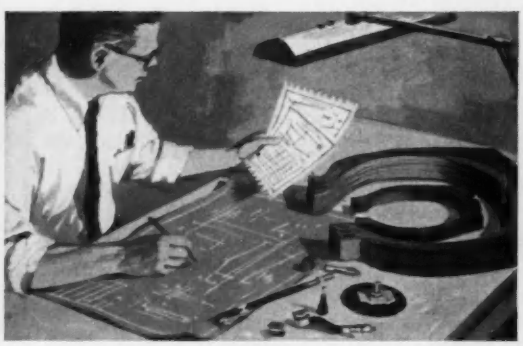
Schrader's famous valve operating principle—the Ace of Standardization —through a program of continuing research on all types of standard tire valves.

greatest enterprise—depends on tire accomplishments

deliver the highest quality valve at the lowest possible price

RUBBER MUST STAND HEAT. Both climatic and brake drum heat can get high enough to weaken and destroy a tire, or shorten its life.

RUBBER MUST STAND ABUSE. Dirt, pressure, bending, shock, chemicals, ozone, moisture condensation . . . just a few of the things that work against tires.



KNOWLEDGE of rubbers for tires and tire valves are closely related, so both industries work together on extremely difficult problems.

STANDARDS ARE HIGH because the Automotive, Tire, and Tire Valve Industries *make* them high—to the benefit of every vehicle everywhere.

In the Automotive, Tire and Tire Valve Industries, research will never stop. Improvements are being made continually. This means each vehicular part, material, or function must constantly be examined and re-examined in relation to every other part, material, or function. As an example, superb types of tires are now in use which would have seemed incredible only a few years ago. And still research in rubber chemistry continues! Right now, Schrader specialists are contributing one improvement after another in valve design, ingredients and practical adaptions to hundreds of wheel sizes and types. Their aim: Ever better tire valves—ever more practical and dependable—to match and serve any vehicle that comes off the production line.

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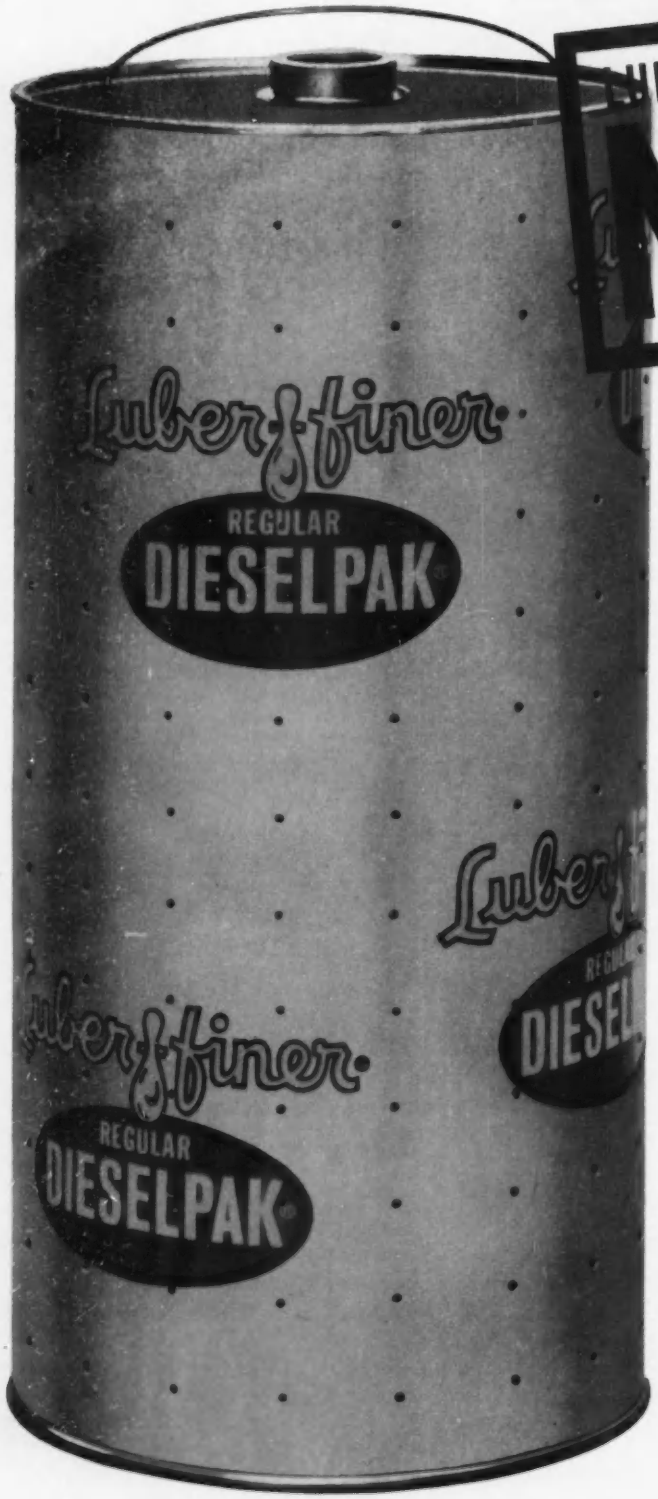

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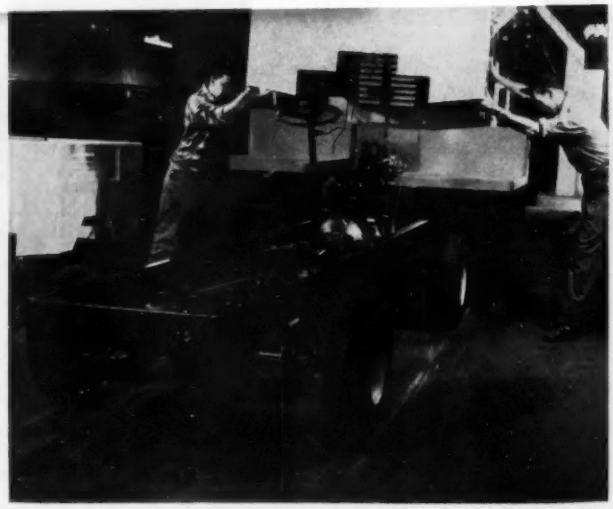

Truck frame built with USS COR-TEN Steel takes terrific torsion strains

In this truck, originally designed for use at Naval air bases, strength was the primary consideration. The builder, Kalamazoo Manufacturing Company, chose USS COR-TEN High-Strength Low-Alloy Steel for the 6-inch frame members.

The grueling acceptance test of their Model 40 (Government version of K45) Platform Truck involved hitting a series of 4-inch-high steel obstacles placed alternately on the right and left sides of the road. This racking motion set up terrific strain due to the twisting of the frame members. The test lasted 8 days, 8 hours a day. At the end of the period, there were no fractures in the COR-TEN Steel and the frame was straight and true.

Results were so good that approval was granted and Kalamazoo subsequently received a contract for 182 trucks for Naval and Marine air bases all over the world. Now Kalamazoo is making them as Model K45's for industrial use and for baggage and cargo handling at airports, with the addition of a conveyor belt.

USS COR-TEN High Strength Steel is widely used for all types of truck frames and bodies. It has a yield point 1½ times that of structural carbon steel, has 4 to 6 times the resistance to atmospheric corrosion, and offers superior resistance to abrasion and impact. What's more, paint on USS COR-TEN Steel lasts up to 50% longer than the same paint system on carbon steel.

For more information, write for a free copy of our COR-TEN Steel booklet. United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

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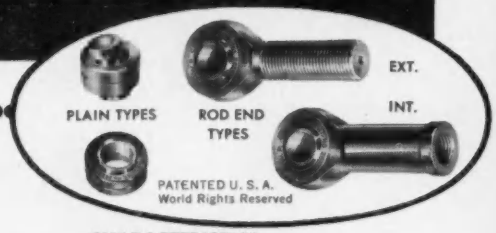

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1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Alloy Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
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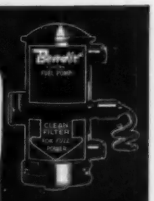

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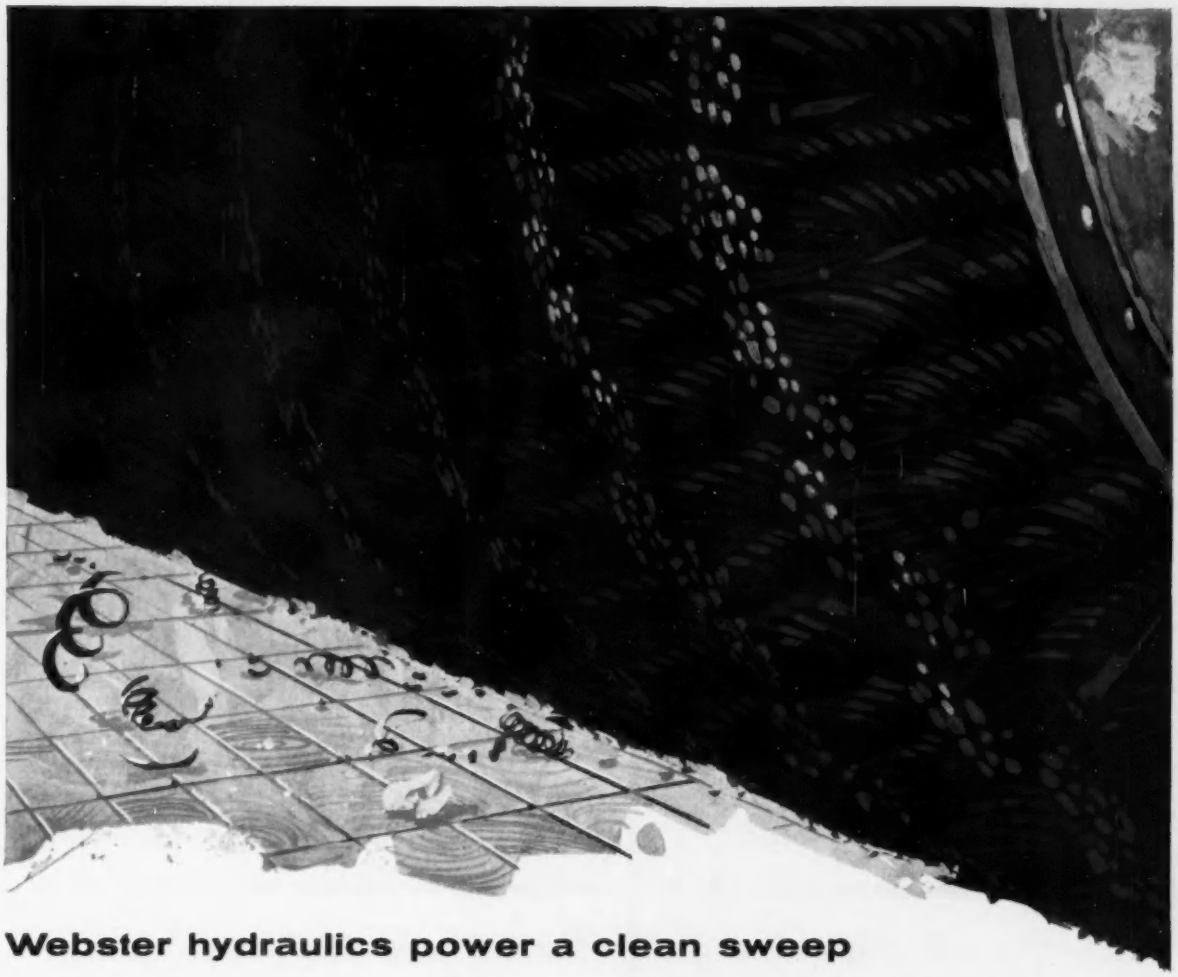


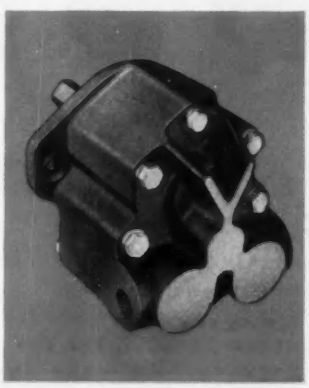
Webster hydraulics power a clean sweep

The business end of an industrial floor sweeper has its work cut out. Cleaning up grease-caked debris, metal chips, oil and grit is a tough demanding chore. It takes power — *versatile* power.

And a Webster HCS hydraulic motor supplies it for one of the most popular sweepers of this type! The HCS drives *both* the brush and the machine — maintains constant brush speed regardless of propelling speed. It has high torque with low power requirements (ideal for this application) and mounts in *any* position.

The HCS, typical of all Webster hydraulic motors and motor-pump combinations, operates at up to 1000 psi, with up to 206 torque pounds/inches per 100 psi (theoretical). It delivers up to 57 hp at speeds up to 2000 rpm.

Would a Webster hydraulic motor, pump or valve adapt to your product? Would it solve a power transmission problem? There's one way to find out — ask the advice of a specially trained Webster hydraulics engineer. There's no obligation. Write for action!



HCS HYDRAULIC MOTOR
Write for complete specifications and performance data.

OIL HYDRAULICS DIVISION

WEBSTER ELECTRIC

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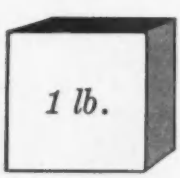
DOW | MAGNESIUM

IN JUST 2 MINUTES, MONEY BY SWITCHING TO

Magnesium's light weight gives you up to **4** *times as many die castings from an equal weight of metal!*

from 1 lb. of zinc	*you get only 1 part*
from 1 lb. of aluminum	*you get only 2⅔ parts*
from 1 lb. of magnesium 	*you get* **4** *parts*

Magnesium gives you other savings, too . . .

- Up to 50% faster casting rate than aluminum
- Easiest of all metals to machine. Less wear and tear on tools. Faster production
- Lightweight magnesium is easier to handle. Saves shipping costs

For more information check with your die casting supplier or write to: Automotive Development Engineering, Magnesium Sales Department 1102EN7, THE DOW CHEMICAL COMPANY, Fisher Building, Detroit, Michigan.

FIGURE HOW YOU CAN SAVE MAGNESIUM DIE CASTINGS

Figure the metal cost per part yourself—

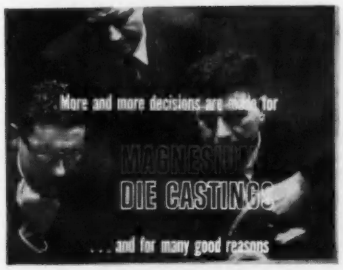
Just insert the price per pound of metal and divide to find the relative cost of zinc, aluminum and magnesium

(price per pound of zinc): $\frac{\text{\_\_\_\_\_}}{1}$ = *(cost per part)*

(price per pound of aluminum): $\frac{\text{\_\_\_\_\_}}{2.67}$ = *(cost per part)*

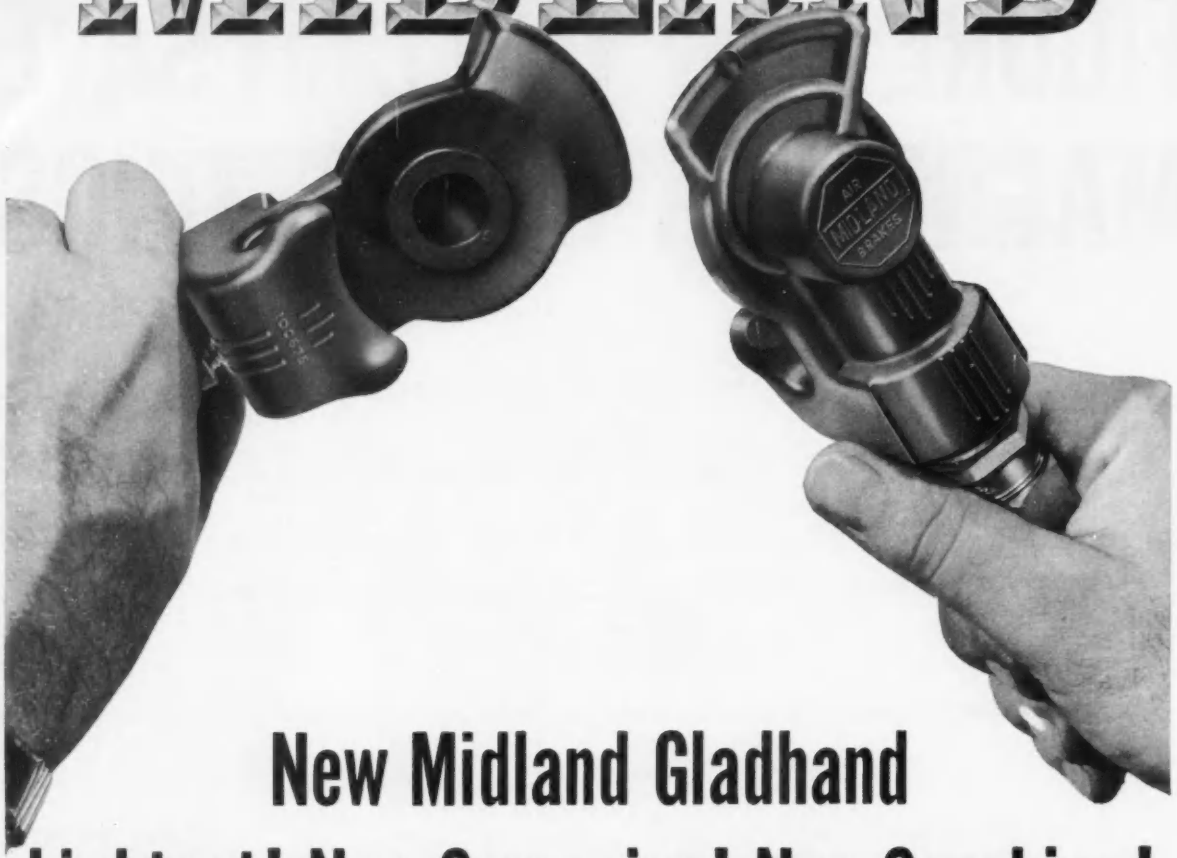
(price per pound of magnesium): $\frac{\text{\_\_\_\_\_}}{4}$ = *(cost per part)*

SEND FOR free Magnesium Die Castings Booklet. Covers design notes, properties, applications, etc. Magnesium Sales Department, THE DOW CHEMICAL COMPANY, Midland, Michigan.



THE DOW CHEMICAL COMPANY · MIDLAND, MICHIGAN

MIDLAND



New Midland Gladhand

Lightest! Non-Corrosive! Non-Sparking!

Made of lightweight, non-corrosive DuPont Delrin (acetal resin), Midland's new Gladhand is interchangeable with present truck-trailer equipment, and couples with all other gladhands.

The new Midland Gladhand offers these exclusive advantages:

- **Lighter Weight**—Twice as light as aluminum. Four times lighter than iron! Yet more resistant to impact than die cast gladhands.
- **Non-Corrosive** — resists salts, oil, grease, gasoline, soaps, solvents and moisture!
- **Non-Conductive and Non-Sparking** — provides greater safety to haulers of flammable loads!
- **Improved Locking** — no springs to break, no balls to jam. Ramp-type lock impervious to road grime.
- **Temperature-Resistant** — performs efficiently at temperatures ranging from —50° to over 190° Fahrenheit!
- **Easy to Couple** — couples easily, quickly — won't gouge or freeze to hands.

The new Midland Gladhand is now available through your Midland distributor. Call him now . . . try a set. And for more information on DuPont Delrin write direct to Midland-Ross in Owosso.

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MIDLAND-ROSS CORPORATION

POWER MIDLAND BRAKES

Owosso Division M-R Owosso, Michigan

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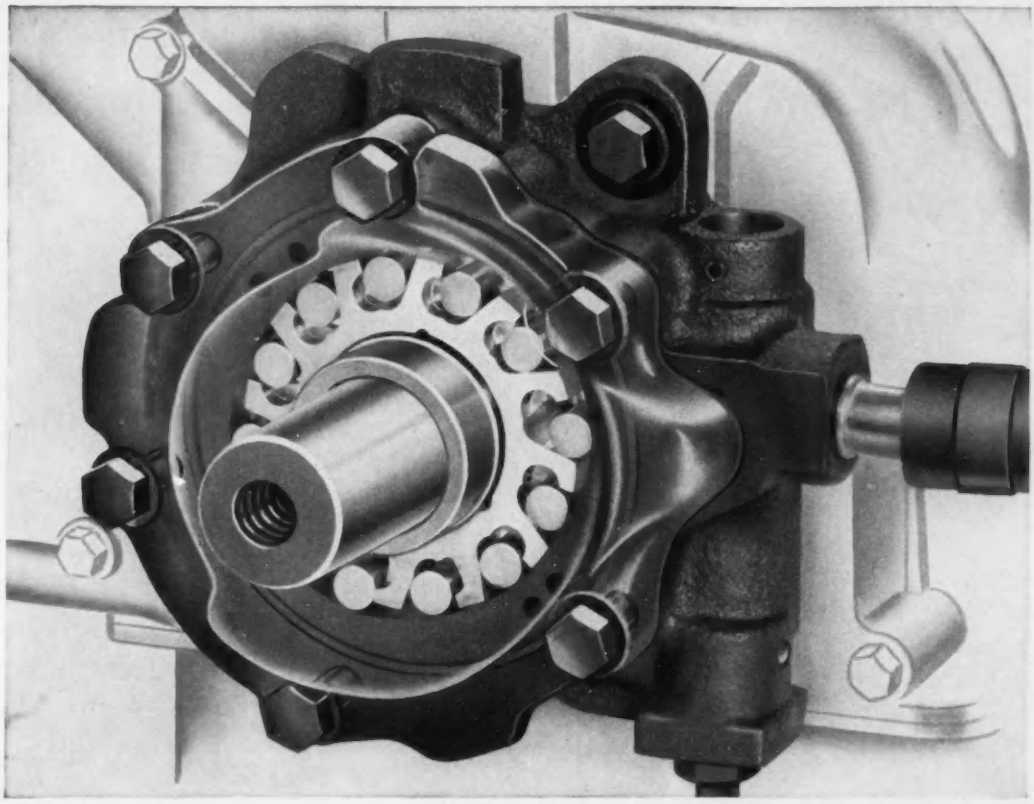

with the Eaton Crankshaft-Driven Power Steering Pump

By eliminating the need for mounting brackets, pulleys, and v-belts, the Eaton Direct Crankshaft-Driven Power Steering Pump saves valuable under-hood space. The oil reservoir is remotely mounted—out of the way. Direct crankshaft drive provides power for steering under all conditions; eliminates the need for belt adjustments.

The Eaton Crankshaft-Driven Pump is an advanced version of the basic Eaton Roll-Pump design which has been performance-proven in operation on many leading passenger cars, motor trucks, and tractors. High efficiency, dependability, quiet operation, and low cost maintenance are tangible benefits inherent in this design.

If you are concerned with improving steering performance while cleaning up engine front end design and gaining additional under-hood space, call on us. Your inquiry will receive immediate attention.

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NEW ONE-OF-A-KIND MICROGRAPH

draws pictures for bearing research

This greatly magnified stylus is drawing a picture of the microscopic imperfections in a bearing raceway . . . measuring each one to within a few millionths of an inch. The picture-on-tape which comes out of this specially modified micrological instrument is an important tool in BCA's research on ball bearing performance.

This is just one of the precision instruments in the Temperature-Humidity-Controlled Instrumentation Room which is the center of BCA research on bearings. The result of this program is revealed in on-the-job performance of BCA bearings. They roll dependably under heavy loads and all kinds of adverse conditions.

New testing facilities at the BCA laboratories also include specially designed equipment, often identical with equipment in customers' plants. Here, BCA bearings are tested to exceed customer specifications *under the exact operating conditions experienced by the customer!*

BCA ball bearings are standard original equipment . . . replacement, too . . . for nearly every kind of industry. For example, automotive, earth moving, agricultural and machine tools. The wide line of ball bearing sizes and types, plus BCA's research and extensive new testing facilities, pays off for bearing users. Consider the performance record of BCA ball bearings the next time you purchase or specify bearings. For more information, or for assistance with bearings problems, contact Bearings Company of America, Division of Federal-Mogul-Bower Bearings, Inc., Lancaster, Pa.

BCA

BEARINGS COMPANY OF AMERICA

ball bearings

DIVISION OF FEDERAL-MOGUL-BOWER BEARINGS, INC.

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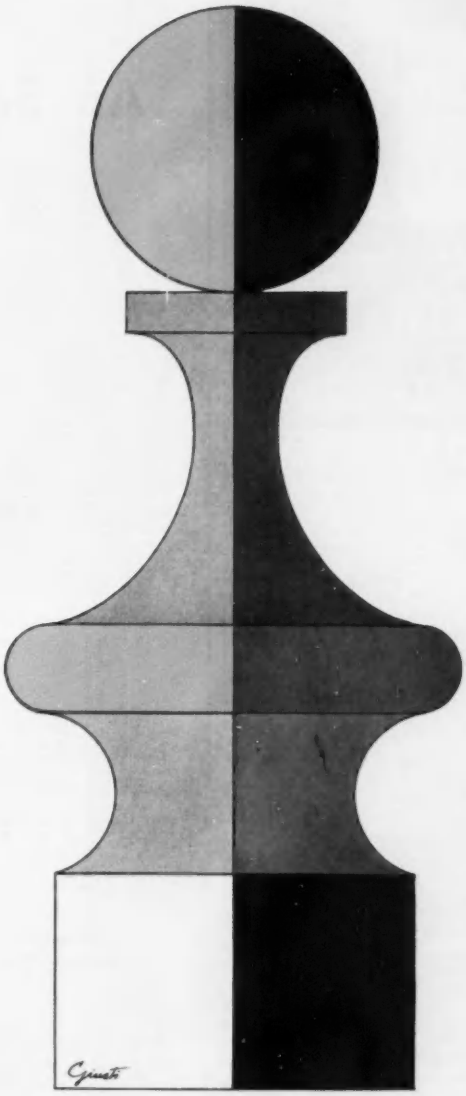

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Western BRASS

Hobbs DUAL CIRCUIT PRESSURE SWITCHES

Add a NEW DIMENSION to Pressure Activation!

DOUBLE DUTY! Disconnects one electrical circuit while placing the other in operation. Industry-approved for a wide range of applications in dual circuit activation of various types of instruments, warning signals, safety devices, fuel pumps — in many other ways for making and breaking circuits. Ideal for locking out a starting motor while the engine is running. Can be used with oil or air . . . or with standpipe, almost any liquid or gas.

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- **Phosphor-bronze diaphragm**
- **Alloy contacts**
- **Preset at factory**

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Also available — a wide selection of single circuit pressure switches. Single terminal; double terminal; normally open; normally closed. Pressure ranges of 3-6, 7-14 and 15-60 psi.

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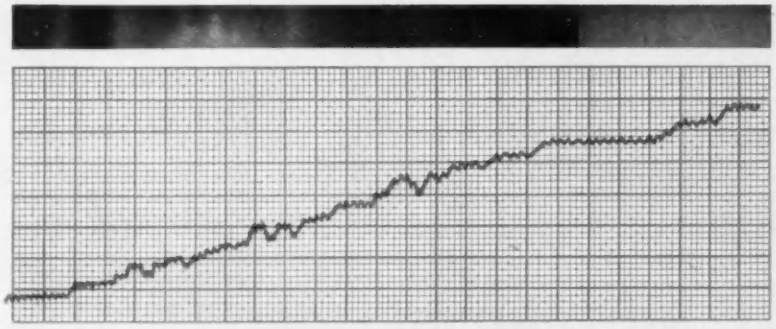
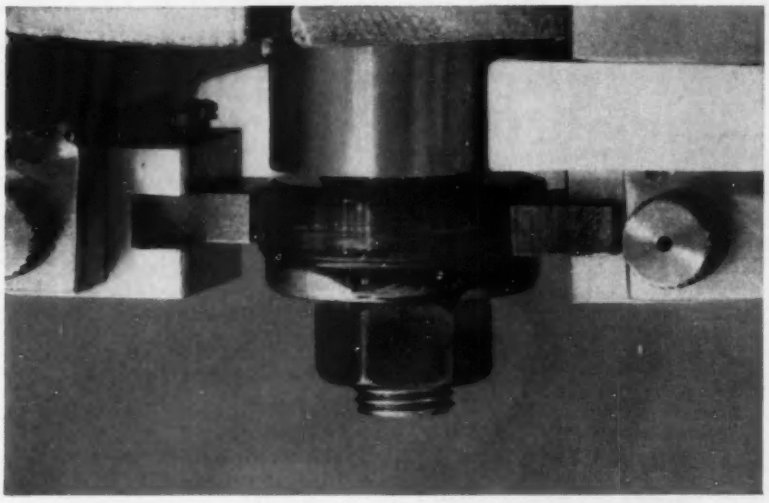
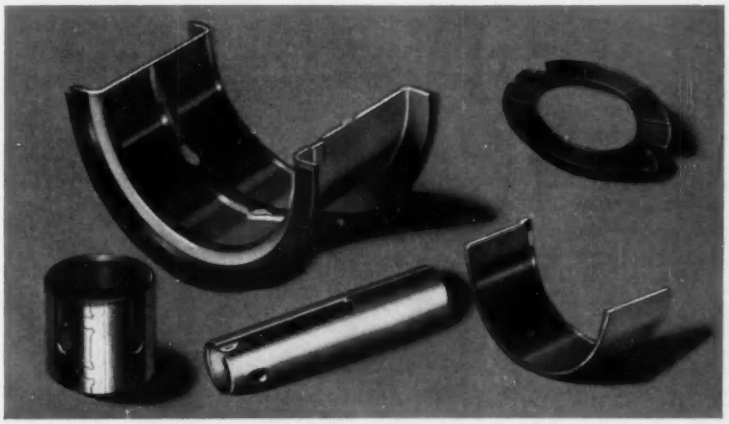




TO TAPE-RECORD THE "HEARTBEAT" OF BEARING METALS UNDER LOAD, WE USE THIS SPECIAL FRICTION AND WEAR TESTER. (left) The result is highly accurate data on the behavior of bearing-metal surfaces, invaluable in our fundamental research into friction. By means of this instrument, we're able to correlate, more closely than ever before, specific alloy compositions with their degree of the "stick-slip" phenomenon (in which one surface sliding over another slides . . . stops . . . slides . . . stops . . . and so on) which accompanies unlubricated sliding action. We can also determine accurately the compatibility of bearing materials with shaft metals in lubricated systems . . . showing us which metal or alloy is most likely to be superior for a given bearing application. In short, this Friction Tester is a fundamental research tool which gives us positive answers to difficult bearing problems, faster than ever before.

ONE REASON WHY F-M SLEEVE BEARINGS and other F-M products give you the finest possible performance — this and the other unusual precision equipment used by Federal-Mogul research. You'll find F-M sleeve bearings used in turbines, engines, and countless other types of power transmission equipment . . . F-M precision thrust washers in pumps, automotive engines and transmissions, motors . . . F-M formed bushings in refrigeration compressors, electric motors . . . and low-cost F-M spacers in motor mounts, machinery, control mechanisms. These are just a few examples.



There's much valuable data in our Design Guides on sleeve bearings, thrust washers, and bushings; and in our brochure on spacers. For your copies, write Federal-Mogul Division, Federal-Mogul-Bower Bearings, Inc., 11035 Shoemaker, Detroit 13, Michigan.

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sleeve bearings
bushings · spacers
thrust washers

DIVISION OF
FEDERAL-MOGUL-BOWER
BEARINGS, INC.

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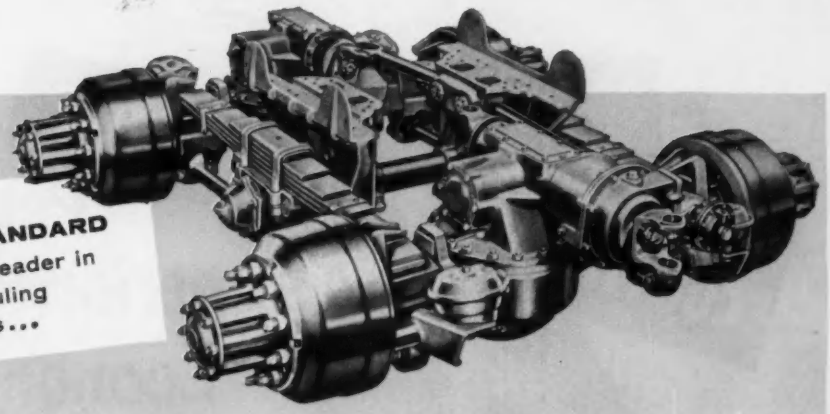


ROCKWELL-STANDARD
Acknowledged Leader in
Rugged Hauling
Operations...

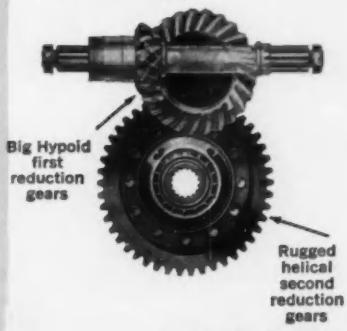
Here's why Timken-Detroit®

DOUBLE-REDUCTION TANDEMS LEAD IN TOP PERFORMANCE—LONG LIFE!

Timken-Detroit Heavy-Duty Tandems with Hypoid Helical Double-Reduction Gears are the big favorites for top performance and long life.
Here are some of the reasons why:

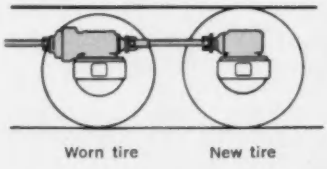
Rugged Hypoid-Helical Double-Reduction Gearing!

Balanced gearing—with two full-sized gear sets working in series to take an equal share of the load—provides a stronger power train with balanced gear set loadings and the widest range of ratios.



Driver Controlled Interaxle Differential!

Allows differential action between the axles to compensate for worn or mismatched tires. Both axles do equal amounts of work . . . can be disengaged at any speed, giving positive through drive when better traction is needed. *Straight-Line Through Drive* eliminates prop shaft angularity . . . increases bearing and gear life, reduces maintenance.



"Torsion-Flow" Axle Shafts and Hot-Forged Housings!

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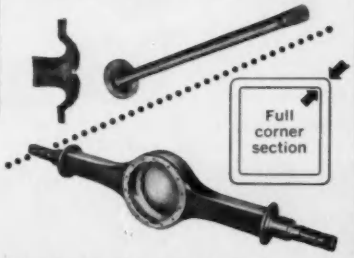

Timken-Detroit Double-Reduction Tandems come in a wide range of capacities—6 models from 34,000 to 65,000 pounds.

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Transmission and Axle Division, Detroit 32, Michigan

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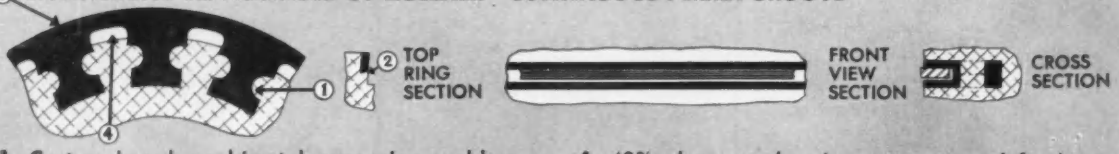
The "Long-Life" Piston with Cast-Anchored Steel Top Ring Section

Superbly Engineered

We suggest an immediate test of these advantages for your engine.

Design adaptable to any type piston

③ ENGINEERING ADVANTAGES OF ZOLLNER "CONTINUOUS PERMA-GROOVE"



1. Cast-anchored—no bimetal expansion problem.
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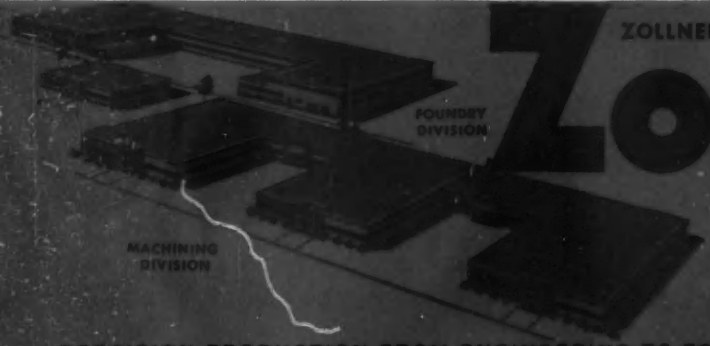
4. 40% aluminum bearing area exposed for heat conductivity and cool operation.
5. Light in weight.



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ZOLLNER

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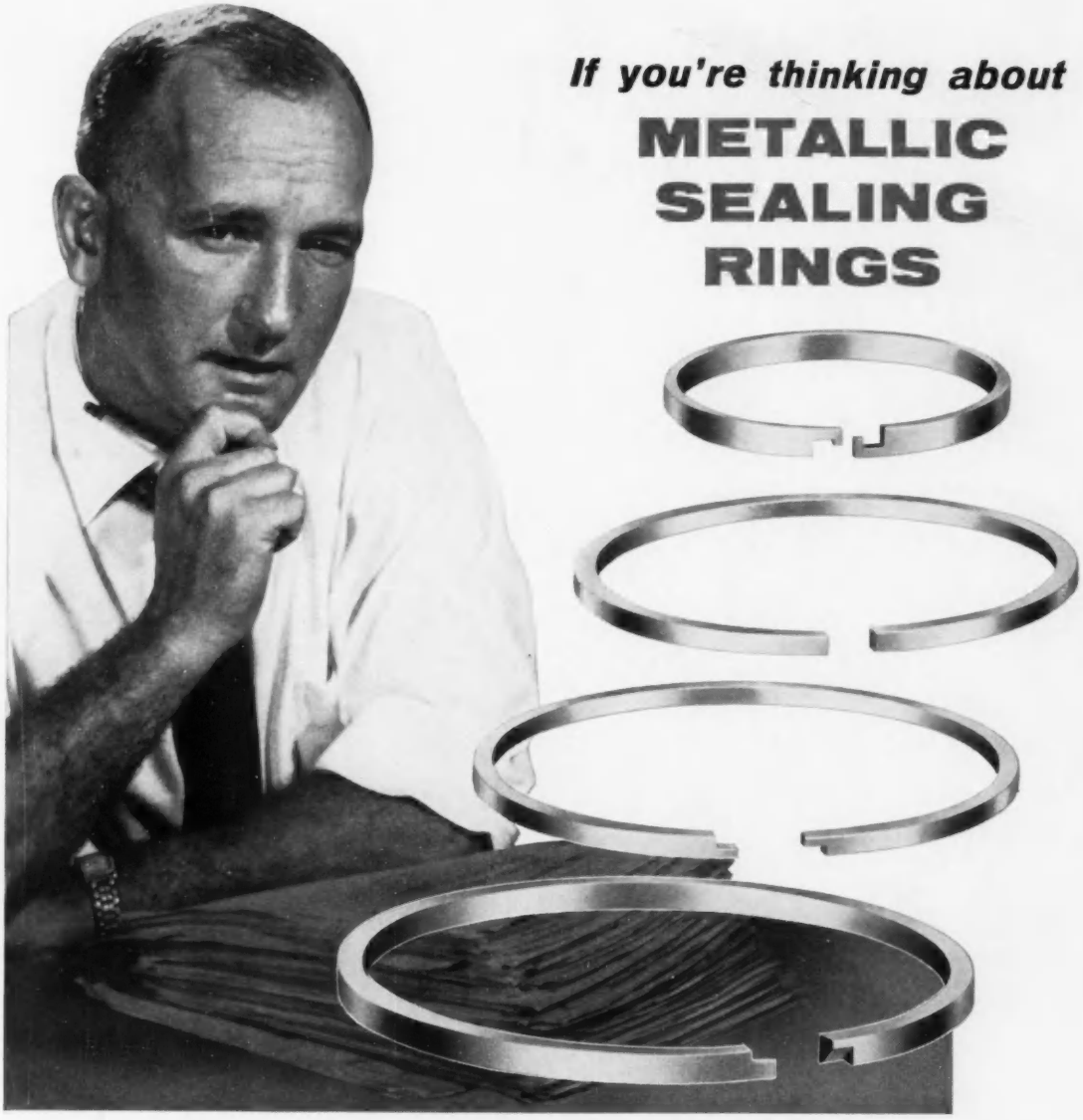
PRECISION PRODUCTION FROM ENGINEERING TO FOUNDRY TO FINISHED PISTONS



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1. You can get just about any kind from WAUSAU, in a wide range of types and sizes, made to your designs or to standard specifications.
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THEY COULDN'T SPOOK THE "JOPLIN GHOST"

It's a three-way tie going into the final round of the 1928 Oklahoma City Open. Two contenders take a birdie four on the first hole. Horton Smith—the "Joplin Ghost"—takes a six. Does it spook him? A steady swing and the ball flies straight as a die to the second hole, a 135 yarder. It rolls into the cup for a hole in one. Lucky? It's what he was aiming at. And Smith went on to win the tournament.

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tapered roller bearings

from the pros of the bearing business